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Ethylene Dibromide (EDB)
Position Document 4

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POSITION DOCUMENT 4

OFFICE OF PESTICIDE PROGRAMS
U.S. ENVIRONMENTAL PROTECTION AGENCY
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This Position Document 4 presents the Agency's final determination regarding the Rebuttable Presumption Against Registration of the pesticidal uses of ethylene dibromide (EDB).

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EXECUTIVE SUMMARY

This Position Document (PD) 4 presents the Agency's final determination regarding the Rebuttable Presumption Against Registration (RPAR) of the pesticidal uses of ethylene dibromide (EDB). The RPAR was initiated by EPA in December, 1977, based on a National Cancer Institute (NCI) study demonstrating the potential of EDB to induce cancer in rats and mice. The basis for the RPAR was the presumed risk of cancer to man as a result of pesticidal exposure to EDB. The RPAR was further supported by additional evidence submitted to the Agency showing EDB to be mutagenic and capable of producing adverse reproductive effects.

In December 1980, the Agency issued a Position Document 2/3 and Notice of Preliminary Determination Concluding the RPAR which proposed several regulatory actions to reduce the human health risks resulting from pesticidal use of EDB. The proposed actions were based on the Agency's risk/benefit analysis of each registered use of EDB.

EDB is registered as a fumigant for preplant application to soil, post-harvest commodity fumigation, spot fumigation of grain milling machinery and several other low-volume uses. The major pesticidal use of EDB is preplant application to soil, which comprises about 90% of domestic use.

This final determination regarding EDB is based on an evaluation of the comments submitted in response to PD 2/3 by the EPA Scientific Advisory Panel, the U.S. Department of Agriculture, industry and the general public. In reaching a final determination, the Agency has reevaluated the health risks and the economic benefits of EDB for the regulatory actions proposed in PD 2/3, and has carried out a thorough scientific and technical review of all comments received.

The Agency has now adequately developed evidence that the preplant soil fumigant uses of EDB are likely to result in leaching to groundwater, and, therefore, in the contamination of human drinking water supplies. The potential contribution of continued soil fumigant use of EDB to the contamination of drinking water poses unacceptable risks and results in an imminent hazard. Consequently, the Agency has determined that it is necessary to immediately discontinue this use of EDB through an emergency suspension order.

The uses of EDB in spot fumigation of grain mills and for fumigation of stored grain pose a significant dietary cancer risk to the general public and high risks to applicators and millworkers. The Agency has determined to cancel these uses. The Agency is extremely concerned about the potential exposure of the public from these uses of EDB and is gathering additional information concerning these exposures. When this additional information has been evaluated, the Agency will consider the need for emergency suspension of these uses.

The Agency has determined that the use of EDB as a quarantine fumigant to ensure fruit fly disinfestation of food commodities shipped out of quarantine areas poses substantial risks to both occupationally exposed workers and to the general public. Further, the Agency has concluded that the human health risks of continued use of EDB as a quarantine fumigant exceed its benefits and that this use must be cancelled. At the present time the Agency recognizes that there are no chemical alternatives for this use and that other alternative technology, including cold storage treatment and irradiation, are not immediately available. The effective date of this cancellation, therefore, has been delayed until September 1, 1984 to allow USDA/APHIS and the industry adequate time to change to alternative means of quarantine fruit fly disinfestation.

The Agency has determined that the use of EDB as a felled log fumigant to control bark beetles poses high cancer risks to applicators and provides little economic benefits. The Agency, therefore, has determined that this use should be cancelled.

For the remaining uses: subterranean and drywood termite control, fumigation of beehive supers, vault fumigation of stored clothing and furniture, and the USDA Japanese Beetle Quarantine Program, the Agency has decided that the final determination regarding these low-volume uses will remain unchanged from the proposed action. The Agency believes there may be some exposure to applicators as a result of these minor uses; however no data are available which demonstrate that these exposures are significant.

These uses will be allowed to continue if certain use restrictions are implemented and additional data requirements are fulfilled. For control of termites, the current label directions will be reinforced and expanded by allowing use only by certified applicators. For the other uses, protective clothing and other low-cost measures, designed to reduce exposures to EDB, will be required. In addition, registrants of products with each of the low-volume uses will be required to conduct studies to determine the levels of EDB in the air to which applicators are exposed, the number of applicators involved in these uses, and the amounts of EDB applied annually.

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I. Introduction

Under the Federal Insecticide, Fungicide, and Rodenticide Act, as amended (FIFRA) (7 U.S.C. Section 136 et seq.) the Environmental Protection Agency (EPA or the Agency) regulates pesticide products. Section 12(a)(1)(A) of FIFRA requires that all pesticide products, unless exempted from regulation, must be registered before they may be sold or distributed. Section 6(b) of FIFRA authorizes the Administrator to issue a Notice of intent to cancel the registration of a pesticide or to change its classification if it appears that the pesticide or its labeling "does not comply with the provisions of FIFRA or, when used in accordance with widespread and commonly recognized practice, generally causes unreasonable adverse effects on the environment."

Unreasonable adverse effects on the environment are defined in FIFRA Section 2(bb) to mean "any unreasonable risk to man or the environment, taking into account the economic, social and environmental costs and benefits of the use of any pesticide." In sum, any decision to register or continue to register a pesticide must weigh both the risks and the benefits from the use of the pesticide.

The Rebuttable Presumption Against Registration (RPAR) process was designed to collect and evaluate benefits and risk information regarding those pesticides which are suspected of causing adverse health or environmental effects, and facilitate regulatory decisions concerning them while allowing interested groups to participate. The regulation governing the RPAR process is 40 CFR 162.11.

On December 14, 1977, the Agency issued a Notice of RPAR and the RPAR Position Document 1 on EDB in the Federal Register (42 F.R. 63134-63161). The PD 1 explained the background and provided supporting data for the presumption of hazard cited in the RPAR Notice. The presumption against the registration of EDB was based on oncogenic, mutagenic and reproductive effects in test animals. The PD 1 provided registrants and other interested parties the opportunity to submit rebuttal comments.

The presumption against EDB could have been rebutted by showing: 1) that the Agency's initial determination of hazard was in error; or 2) by demonstrating that existing use patterns and the resulting exposure to EDB did not induce any significant adverse effects. (See 40 CFR 162.11 (a)(4)) Respondents were also asked to submit evidence of the social, economic, and environmental benefits from the uses of the pesticide. See 40 CFR 162.11 (a)(5)(iii).

On December 10, 1980, the Agency issued "Pesticide Products Containing Ethylene Dibromide (EDB); Preliminary Notice of Determination Concluding the Rebuttable Presumption Against Registration; Availability of Position Document 2/3." 45 FR: 81516-81524). In the PD 2/3, the Agency concluded that the presumptions of oncogenicity, mutagenicity, and reproductive effects were not rebutted. The PD 2/3 also presented the Agency's evaluation of rebuttal comments received in responnse to the original RPAR Notice. It provided the Agency's analysis of the risks and benefits associated with the use of EDB and it presented the regulatory options that were considered for purposes of risk reduction. Finally, the PD 2/3 contained the Agency's proposed regulatory approach to conclude the RPAR. The PD 2/3 is summarized below and included in its entirety as Appendix I.

Summary of PD 2/3

The Position Document (PD) 2/3 proposed several regulatory actions to reduce the human health risks resulting from registered pesticidal uses of ethylene dibromide (EDB). These proposed actions were based on the Agency's determination that certain uses of EDB resulted in unreasonable adverse effects to man. All of the registered uses of EDB were examined in this document. These include: preplant fumigation of soil (to control nematodes); fumigation of stored grains (to control insects); spot fumigation of grain milling machinery (to control insects); post-harvest fumigation of citrus, tropical fruits, and vegetables under USDA Animal, Plant and Health Inspection Service (APHIS) quarantine (to control fruit flies); fumigation of felled logs to control bark beetles); fumigation of stored beehive supers and honeycombs (to control the greater wax moth) vault-fumigation of stored furniture and clothing (to control various pests); treatment of plants, soil and grass sod in accordance with the USDA/APHIS Japanese Beetle Quarantine Program; and fumigation beneath concrete slab foundations of buildings and porches to control subterranean termites, and spot fumigation of their galleries to control drywood termites.

The first regulatory action the Agency proposed was to allow registration to continue for preplant soil fumigation, the largest volume use of EDB. However, the Agency would permit this use only if certain restrictions were implemented and additional data requirements were fulfilled. Specifically, the Agency would require applicators to wear respirators and protective clothing; reentry into a treated field would also be prohibited for 24 hours following fumigation. The Agency would have required soil fumigant registrants to conduct studies to determine if this use results in groundwater contamination. When results from these studies were available, the Agency would reexamine the adequacy of its regulatory measures for this use.

Second, the Agency proposed to cancel the EDB registrations for two other major uses; fumigation of stored grains and spot fumigation of grain milling machinery. The bases for these proposed cancellations was that the public health risks of cancer, heritable genetic damage, and reproductive disorders outweighed the economic benefits of these uses. The Agency concluded that residues of EDB contaminate the human diet as a result of these registered uses. Applicators, persons near a treatment site and workers who handle treated commodities are also exposed to significant levels of EDB via inhalation and dermal contact.

Third, the Agency proposed that on July 1, 1983, EDB registrations for post-harvest fumigation of citrus, tropical fruits and vegetables would be cancelled. The interim period would provide time for the development and implementation of efficacious alternatives.

Fourth, the Agency proposed to cancel the EDB registration for fumigation of felled logs, a relatively low volume use. The basis for this action is the Agency's determination that the potential risks to applicators outweigh the economic benefits of this use.

Finally, for the remaining uses: fumigation of beehive supers, vault fumigation of stored clothing and furniture, and the USDA's Japanese Beetle Quarantine Program, the Agency proposed to allow these uses to continue only if certain use restrictions were implemented and additional data requirements were fulfilled. Specifically, the Agency would require protective clothing and other low-cost measures designed to reduce applicator exposures to EDB. In addition, the Agency would require registrants of products with each of these uses to conduct studies to determine the EDB air levels to which applicators are exposed, the number of applicators involved in these uses, and the amounts of EDB applied annually for these uses.

II. Analysis of PD 2/3 Comments on Exposure and Risk

The Agency has revised some aspects of its assessment of risks, benefits and regulatory requirements in accordance with additional information provided by the public, United States Department of Agriculture (USDA), Science Advisory Panel (SAP) and other sources. Except as discussed below and in Section III, other aspects of the analysis presented in the PD 2/3 are unchanged.

A. Comments Relating to Exposure

The Agency has received comments relating to exposure to EDB as follows:

Use pattern	Commenter
Preplant Soil Fumigation	(#24) Great Lakes Chemical Corp. (#34) Dow Chemical Co.
Spot Fumigation Grain Milling Machinery	(# 2) Millers' National Federation (#22) Ferguson Fumigants, Inc.
Fumigation of Stored Grain	(#2) Millers' National Federation
Quarantine Fumigation	(#23) Hawaii Papaya Industry Assoc.
	(#25 and #25A) Florida Dept. of Citrus
Felled Log Fumigation	(#15 and #15A) Colorado State Forest Service

1. Applicator Exposure

a. Preplant Soil Fumigation

Dow Chemical Co., has submitted new exposure studies for this use of EDB (Skoronski, 1979, and Martin, 1980). These studies, along with some clarifying information provided by Dow (Martin, 1982), have been evaluated by the Agency. The air levels of EDB reported in these studies are substantially higher than those used by the Agency for the PD 2/3 applicator exposure assessment. The PD 4 applicator exposure assessment for this use has been modified accordingly (see Section III).

Great Lakes Chemical Co. (Comment #24) stated that it is unrealistic to assume that 100% of inhaled EDB is absorbed by the lung; however, Great Lakes did not suggest or provide a basis for choosing an alternative. Great Lakes stated that a respiratory rate of 0.6 m^3/hr would be a more appropriate value to use than the 1.2 m^3/hr value for moderate activity used in PD 2/3, and that the NIOSH EDB Criteria Document (NIOSH, 1977) used this 0.6 m^3/hr figure. The document did use the 0.6 m^3/hr value, but it is not stated what level of physical activity this breathing rate corresponds. The Agency consistently uses a 1.2m^3/hr value for males engaged in light to moderate work (Hayes, 1975).

Great Lakes offered "more realistic" estimates of annual and lifetime durations of applicator exposures. The Agency considers these estimates more reliable (Weidman, 1981) than those used in PD 2/3 and they have been used for the modified applicator exposure estimates in this PD 4 (see Section III A).

Great Lakes stated that requiring applicators to wear respirators is unnecessary since even the highest lifetime exposure calculated in PD 2/3 (Table 16, p. 48) is less than the NIOSH recommended standard of 130 ppb (NIOSH, 1977). Great Lakes suggested that the Agency consider as an alternative regulatory option that respirators be required only "... when the product is exposed to the environment during small spills, repairs, calibration, transfers or sampling." The highest exposure in Table 16 (532.4 mg/yr for pineapple soil fumigation application) corresponds to a lifetime exposure of about 300 mg/kg. This compares to the NIOSH figure of 686 mg/kg which is stated to be "substantially below that total dose known to induce adverse effects in experimental animals." This dose level was published prior to findings of the cancer inducing potential of EDB. The Agency rejects the use of this exposure level in regulating a cancer causing chemical, such as EDB. It is Agency policy that, lacking valid scientific evidence supporting a threshold (below which no risk of cancer exists), any exposures other than zero, must be presumed to be attended by a risk of cancer in humans. The Agency has determined that the risk posed to applicators, as well as the risk posed by contamination of ground water aquifers (as discussed in Section III E and H of this document) from this use of EDB, require emergency suspension of registrations of this use. The revised exposure assessment for this use is discussed in detail in Section III of this document.

b. Spot Fumigation of Grain Milling Machinery

The Miller's National Federation (MNF) (Comment #2) commented that the Agency's calculation of applicator exposure during the spot fumigation of milling machinery did not consider the case in which respirators are worn properly, or take into account the rotation of applicators . EPA, however, evaluated this situation in the PD 2/3 (see case I, table 18, p.54 of PD 2/3). The text describing this table (p. 53 of PD 2/3, second paragraph) contains a transcription error; this sentence should read: "Alternatively, with proper use of the respirator and rotation of applicators, an inhalation exposure of 4.3 - 12.5 mg/kg/yr is estimated."

MNF stated that the Agency incorrectly used an air level value of 3.8 ppm (the limit of detection) as a persistence level for a full 8-hour day during normal operations, even though air sampling was discontinued when the limit of detection was reached. The Agency agrees that this approach leads to a bias toward higher exposure, but in the absence of more precise data, this approach is considered to be a prudent and reasonable approach.

MNF stated that the exposure ranges for applicators and workers (p. 65 in PD 2/3) overlap, and that this overlap represents "a highly improbable situation". MNF, however, did not point out which assumptions or calculations are incorrect or could lead to this "improbable situation." The use of protective equipment by applicators and not millworkers, and the significantly longer exposure of millworkers provides explanation for this result.

MNF urged the Agency to consider requiring respirators only during the high exposure times (opening or opening and start-up) to reduce risk. The Agency fully considered the use of protective equipment in this use, but concluded any realistic assessment of the effectiveness of such a restriction would still leave significant applicator exposure. This exposure combined with the dietary exposure to the general public compelled the conclusion that this use presents unreasonable adverse effects.

Ferguson Fumigants, Inc. (Comment #22) reemphasized their claim that applicator exposure is "nil" since an essentially closed system is employed. No new data were provided to support this comment, and the available information, instead, demonstrates significant exposure potential.

c. Quarantine Fumigation

Florida Dept. of Citrus (FDC) (Comments #25 and #25A) challenged the data on levels of EDB used to calculate exposure to fork-lift truck operators at port warehouses. The Agency acknowledges that the data used were limited. However, the Agency believes that the difference in the levels reported is probably the result of the length of time the fruit has been in storage in the warehouse, and continues to believe the levels used in the PD 2/3 were appropriate.

FDC claims that the Agency based its calculations of average inhalation exposure to warehouse workers on two exaggerated assumptions. First, that workers were exposed for 155 days a year. The Agency agrees with FDC that fumigation stations do not operate 155 days per year. The Agency, however, calculated the applicator exposure at the fumigation station in the PD 2/3 at 112 days per year (the average number of operating days at Wahneta during the 1978-1980 seasons). Because bleed-off from the cartons and fruit continues beyond the day of treatment, the Agency believes that the exposure period of 155 days during the period from October through May is not an exaggerated assumption for warehouse workers who handle the fruit after treatment.

Second, FDC states that work at the citrus fumigation stations and port warehouses can hardly be classified as "heavy activity" because such work does not involve much exertion or heavy physical activity. The Agency has now used a breathing rate of 1.2 m^3/hr, the applicable rate for males engaged in "light to moderate activity" in calculating exposure (see Section III), instead of 1.8 m^3/hr as used in the PD 2/3.

The Hawaii Papaya Industry Association (Comment #23) submitted two studies of air levels of EDB in papaya fumigation plants. The NIOSH study submitted has been reviewed, but cannot be used as the basis for a worker exposure assessment, because of significant deficiencies, i.e., inadequate method of analysis, sample size, and protocol in the design of the study (Day, 1981). The second study submitted by the Hawaii Papaya Industry Association (Hertlein and Hagadone, 1981) has been reviewed by the Agency and can be used for the calculation of exposure to workers at papaya fumigation sites. This study is the basis for the exposure analysis presented in Section III.

The Agency has also received a summary of a monitoring study conducted by NIOSH at Hilo, Hawaii. The values in this study are slightly lower than those found by Hertlein and Hagadone.

The reduction appears to have occurred because the Papaya industry now employs charcoal filtration in refrigeration rooms and fumigation chambers. However, these results are within an order of magnitude of the Hertlein and Hagadone results and would not result in a substantial change in exposure estimates.

d. Felled Log Fumigation

In PD 2/3, the Agency stated that no data were available on applicator exposures during felled log fumigation. In response to the PD 2/3, the Colorado State Forest Service (CSFS) (Comment #15A) submitted two exposure studies reported in a 1973 USDA/Forest Service Document (Undi, 1973). These studies have been accepted and are the basis for the exposure assessment presented in Section III.

CSFS stated that the use concentration of EDB is 4.5%, not 23% as stated in PD 2/3. The Agency has confirmed that the typical concentration of EDB used against the mountain pine beetle (the main target pest of the forestry use of EDB) is a 5:1 volume/volume dilution of a 23% formulation. This corresponds to a 4.76% weight/weight use concentration. This figure has been used for the exposure assessment in Section III.

2. Dietary Exposure

a. Preplant Soil Fumigation

Great Lakes Chemical Corp. (Comment #24) stated that the analytical method in a California Department of Food and Agriculture (CDFA) study (Maddy et al., 1979) has a qualitative limit of detection (the minimum concentration which produces a signal which can be unambiguously recognized above background) of 0.1 ppb. Great Lakes contended that this value is the proper one to use in the dietary exposure calculations, rather than the quantitative detection limit (the lowest signal which can be used to reproducibly quantify the amount of chemical present) of 1 ppb, which was used in PD 2/3. However, scientists familiar with the CDFA method (Communications, J.C. Reinert, T. Jackson, D. Rains) indicate that for some crops analyzed, the qualitative limit of detection (for a 4:1 signal: noise ratio) is well above 0.1 ppb.

Thus, the Agency believes that recalculating the dietary exposure for preplant soil fumigation is unwarranted. This is because choice of a proper residue level is uncertain and, furthermore, any change would result in a change of less than an order of magnitude in dietary exposure. As noted by Great Lakes, the estimated dietary exposure is hypothetical, and any actual residues of EDB in crops, would probably be at concentrations

below this level. The Agency estimation of dietary exposure from preplant soil fumigation should thus be considered a worst case projection.
Very recently, CDFA reported finding detectable residues of EDB in carrots grown in EDB-fumigated soil (personal communication, R. Johnson and K. Maddy, CDFA, September, 1983). These results have not yet been evaluated by the Agency.

Dow Chemical Co. (Comment #34) has submitted a series of published papers and a theoretical treatise on the fate of EDB in soil in order to preclude the need to conduct field dissipation and leaching studies. Dow's arguments, while well presented, are not persuaive regarding potential contamination of groundwater as a result of this EDB use. Indeed, recently developed groundwater monitoring and tests of soil movement of EDB demonstrate that continued use of EDB as a soil fumigant can be expected to contaminate groundwater sources.

b. Spot Fumigation of Milling Machinery

The Millers' National Federation (MNF) (Comment #2) stated that the Agency's PD 2/3 estimate of dietary exposure was based on incomplete and contradictory data which was derived from samples without defined histories. MNF argued that the Agency could not reach a conclusion regarding the origin of EDB residues (whether they come from the spot fumigation use or bulk grain fumigation).

Ferguson Fumigants, Inc. (Comment #22) suggests that the dietary exposure to EDB which results from the spot machinery use is insignificant when compared to total dietary burden. Although the Agency agrees that it is currently unable to calculate the precise proportion of the total dietary burden from grain products attributable to spot fumigation, it does have data showing that this use may contribute significantly to this dietary burden (see discussion in III D).

The SAP expressed its great concern over the potential human dietary exposure to EDB residues in finished bakery products as a result of the spot fumigation of milling machinery and stored grain fumigation, and recommended that, because of the extremely large population potentially at risk, these uses should be cancelled until such time as convincing evidence exists that these uses present no unreasonable risk to consumers.

c. Quarantine Fumigation

The Florida Department of Citrus (FDC) (Comments #25 and 25A) stated that the fresh citrus food factor used in PD 2/3 (3.8%) was too high. Based on information contained in a 1979 report from the Florida Crop and Livestock Reporting Service, FDC calculated a fresh citrus food factor of 2.2%. The Agency agrees that the 3.8% value used in PD 2/3 was too high. The Agency has recalculated this value for fresh citrus only (Reinert, 1982b) and obtained a value of 2.8%. This value is close to that proposed by FDC and has been used in the PD 4 dietary exposure assessment (see Section III).

FDC claimed that the EDB residue level in citrus used in the PD 2/3 was too high. It was estimated from a derived residue loss equation and used for the dietary exposure assessment. FDC presented actual analyses of EDB residues in the edible portion of citrus at various times after fumigation (King et al. , 1980). The results for the edible portion of grapefruits (avg. residue level = 0.027 ppm) and oranges (0.029 ppm) seven days after fumigation are in good agreement with the most recent data of Maddy (Maddy, 1981a), which have been used in the PD 4 dietary exposure assessment (see Section III). Very recent data submitted by USDA (USDA, September, 1983) are discussed in Section III.

3. Other Exposure

FDC suggested that, although the potential exposure of populations in private residences located a short distance from fumigation stations is low, increasing the exhaust stack height from 10 to 30 meters could aid in reducing ground level EDB concentrations by increasing atmospheric dispersion. The Agency agrees that EDB exposure to the general population should be reduced to the lowest level feasible in areas surrounding citrus fumigation stations.

B. Comments Relating to Hazards

1. Oncogenicity

The Millers National Federation (MNF) (Comment #2) and the Occidental Chemical Company (Comment #28) both stated that the route of administration in the 1977 NCI study, intubation, was inappropriate because human exposures would be primarily by inhalation. The Agency's Carcinogen Assessment Group (CAG) recognizes the difficulties in determining the human inhalation dose from a rodent intubation study. However, two inhalation studies in rodents have since been completed (Wong *et al.*, 1979 and NCI, 1980)and the risk estimate for inhalation is now based on a rat inhalation study.

The Florida Department of Citrus (FDC) (Comments #25 and #25A) stated in their comments that results from bioassays cannot properly be used to calculate risk estimates for humans, since it has not been demonstrated that humans metabolize a substance in the same way as the animal species used in the experiment. The CAG agrees that there is no known evidence which demonstrates that humans metabolize EDB in the same manner as do experimental animals. However, there is also no evidence demonstrating that humans do *not* metabolize EDB in the same manner as do experimental animal. In the absence of information concerning the metabolism of the compound in humans, it is prudent to assume that animals are adequate models for predicting human effects. Because EDB is a direct-acting alkylating agent and induces carcinomas in both rats and mice, the assumption that the effects will be the same for humans is particularly reasonable.

FDC comments that the one-hit model for assessing mutagenic and carcinogenic potential is unsatisfactory. The FDC also stated their opinion that the risk estimates presented in the PD 2/3 are probably exaggerated since the one-hit, no-threshold model is the most conservative method of calculation. FDC suggests that the threshold concept is more valid and practical. The dominant scientific view of carcinogenicity is that most agents that cause cancer also cause irreversible DNA damage. There is substantial evidence from mutagenicity studies that the biological response characteristic of mutagenesis is associated with a linear nonthreshold dose-response relationship, and this model is appropriate. This is particularly [illegible]e at the lower end of the dose-response curve which represents typical human exposures. The linear non-threshold model is also consistent with the available epidemiological cancer studies. (e.g., radiation-induced leukemia, breast and thyroid cancer, and liver cancer induced by aflatoxin in the diet).

There is also some evidence from animal experiments consistent with this model (e.g., liver tumors induced in mice by 2-acetylaminofluorene).

Because it has the best scientific basis of any of the current mathematical extrapolation models, the linear nonthreshold model has been adopted as the primary basis for risk extrapolation to low levels of the dose-response relationship. The risk estimates made with this model should be regarded as conservative, representing the most plausible upper limit for risk, i.e., the true limit is not likely to be higher than the estimate, but it could be lower. Therefore the Agency agrees that this model may be conservative. The risk estimate presented in the PD 2/3, based on this procedure, gave a plausible upper limit for risk.

The CAG has now adopted a new procedure for estimating the cancer risks for EDB dietary exposure. The one-hit model with "Weibull" timing, which is conceptually similar to, but operationally more systematic than the one-hit model is now used to estimate cancer risk for EDB, to adjust for the short duration of the study (CAG, 1982a).

Other models, such as the multi-stage model, have also been suggested for use in extrapolating EDB cancer risks (USDA draft report, 1983). However, this model, as proposed by USDA, did not take into account the extremely rapid onset of tumor or the short duration of the study (Burin, 1983). Furthermore, the complete model, proposed by USDA, is not yet available for detailed scientific review. The Agency considers the new CAG model to be the best model currently available for determination of EDB dietary cancer risk.

FDC also commented that a major fault of the NCI dietary studies was a failure to select the proper dose of EDB. The dose was adjusted during the study and was finally calculated as a time-weighted average dose. This resulted in a poor survival rate. In response, the CAG considers that the adjustment of dose during the course of the study makes the calculation of effective dose uncertain. However, it does not negate the positive carcinogenic response to EDB observed in the studies. The FDC further commented that the evidence regarding oncogenicity falls short of establishing a connection between cancer and EDB residues in food. They note that intubation (introducing EDB directly into the stomach of laboratory animals) is recognized by EPA as an inappropriate methodology for assessing risk from foods ingested orally. They also point out that the scientific community, in making risk assessments from food additives, has rejected such studies for this reason.

The CAG, however, has compared tumor responses where dibromochloropropane was administered via both gavage and diet, and found no significant difference. And EDB and DBCP are:
1) structurally related halogenated aliphatic hydrocarbons,
2) mutagenic, and 3) induce a carcinogenic response in the stomachs of rats and mice. The CAG, therefore, regards the use of an intubation study to assess the carcinogenic risk of EDB residues in food as appropriate. In addition, the risk estimates have been adjusted to reflect the small degree of difference in effects between dietary and gavage administration seen in the DBCP studies.

Dow Chemical Co. (Comment #34) commented that the Agency's wholesale rejection of the Dow rat inhalation study (PD 2/3, pp. 12-13) for risk assessment is unfortunate. Dow added that this is the only study that examines effects after exposures are discontinued -- a situation analogous to the infrequent and intermittent exposures experienced by workers. The Dow Chemical Co. rat inhalation study (Nitschke, et al. , 1980) was reviewed by the CAG.

The Agency rejects these comments. The CAG concluded that the study is inadequate to assess carcinogenicity in rats because 1) the duration of exposure was short (a maximum of 13 weeks), and 2) the period of observation post exposure (88 to 89 days) was too short to determine whether it demonstrated development of a carcinogenic response.

The FDC argued that two studies on occupational exposures to EDB from the Octel Company were valid. The comment claims that EPA has disregarded any epidemiology studies that show no effects.

The Agency disregarded the Octel studies, however, not because they showed no effects, but because both embodied serious flaws as noted in the PD 2/3.

The Ethyl Corporation, (Comment #19) discussed the Octel mortality survey on 117 persons occupationally exposed to EDB where employment was known to exceed four years. Ethyl noted that the Agency position was that, since no monitoring or exposure levels of EDB in the plant are discussed, the entire study is useless. Ethyl Corporation asked that the EPA position on this study be reconsidered, in view of what Ethyl characterized as the considerable importance of this study, as evidence of human exposures to significant levels of EDB over a period of several years. Since receipt of EDB exposure estimates from Ethyl Corporation, the Agency has reviewed the validity of the Octel mortality survey (CAG, 1982d). In addition to the key argument against the study's validity, (the lack of monitoring data on exposure to EDB, discussed in the PD 2/3), other criticisms apply. They are as follows:

- Small study population. The study population consisted of 117 employees. A group this size is not large enough to adequately detect the presence of a cancer risk. Age-specific cancer mortality rates for this study population were derived based on only 4 observed deaths in the entire group of 117 compared against the person years at risk (broken down by age category over the time period 1940 to 1977). These rates were then compared to rates for similar categories in Southwest England in 1961 and 1970. It was calculated that 8.4 cancer deaths could be expected to occur in the 117 group members during the followup period. This is an insufficient size of a study group, statistically, at least a 2-fold risk of cancer generally must be found at a power equal to 0.8, in order to detect a statistical difference at probability of 0.05.

- Invalid cohort selection. The author decided to drop 84 people from the study for whom he had no further information and another 29 because incomplete information indicated a length of employment of less than 4 years. Together, these two groups represent 47% of the original list of 214 names of individuals who had been reported to have worked there since 1940. Because almost half of the potentially exposed members were arbitrarily excluded from the study, the potential for bias is considerable. Furthermore, the criteria for exclusion of people from the study group were loosely defined.

- o Duration of EDB production. Although the author notes that this plant has produced bromine from 1940 to 1973, nowhere is it mentioned when the production of EDB began, although it is stated that EDB production ceased in 1970. Because some workers may have terminated employment before or shortly after EDB production began, this raises the question of whether all of the 117 "selected" employees were exposed to EDB for 4 years, the minimum duration acceptable for this study.

In short, the methodological inadequacies of this study preclude its use in an evaluation of the carcinogenicity of EDB to man.

The major flaws in the second Octel study, "Dibromoethane: A survey of employee records at Almwch Factory" (Turner, 1976) are listed below:

- o Invalid age comparison. The author compared a crude mortality rate by cause, derived from his study cohort during the period 1960 to 1975, with an age-specific rate of a control population of males ages 45 to 64, residing in Gwynedd, Wales in 1974. The average age of the cohort population was 40; the average age of the control group was much higher. Therefore, because of the differences in the ages of the groups, the comparison of the two groups could not be expected to demonstrate any excess mortality in the study group. Details of this calculation are addressed in the CAG memo addressing comments to EDB risk (CAG, 1982b).

- o Invalid person-years calculation. Twenty-eight deaths in the study group were noted during the period 1960 to 1975, yet person-years were counted as if those who died lived to the end of 1975. This biased downward the death rates of the study group.
- o Small study group. As in the first Octel study, the size of the population is not statistically large enough to assure that it would detect the presence of a significant cancer risk.

In summary, the two studies described above are not considered to be adequate to evaluate the carcinogenic potential of EDB.

2. Mutagenicity

The Agency did not receive any comments regarding the presumption of mutagenicity. The Agency concludes that the qualitative mutagenic criteria are fully established for EDB In addition, the mutagenic properties of EDB support the Agency's position that EDB is a direct acting carcinogenic agent. Since the Agency issued the PD 2/3, the state-of-the-art in mutagenic risk assessment has developed to the point where one can attempt to estimate risk to humans exposed to many chemical mutagens (Banbury Report 1979). The Agency is working toward the goal of basing regulatory decisions on quantitative mutagenic risk assessments. Until the Agency has such a capability, our regulatory position is to reduce exposure to mutagens to the lowest levels practicable.

3. Reproductive Effects

Two unpublished studies addressing the adverse reproductive effects of EDB were submitted in response to the PD 2/3. These studies are discussed below.

a. Ter Haar, 1981

Ter Haar (1981) compared the frequency distribution of sperm concentrations in workers exposed to EDB with the frequency distribution in clinical studies of fertile men (Smith and Steinberger, 1977, Nelson and Bunge, 1974). He reported that these frequency distributions did not differ significantly.

The Agency concludes that there are a number of inadequacies in the Ter Haar (1981) study. Some of the more significant ones are:

- The criteria for determining adverse reproductive function are not defined.

- No attempt was made to determine if sperm concentration from workers exposed to EDB accurately reflected true daily sperm production.
- There was no matching control group, and there was no adequate comparison made between exposed and non-exposed workers.

Because of these and other inadequacies, this study cannot be accepted as useful evidence for the lack of adverse reproductive effects in workers exposed to EDB.

b. Levine et al., 1981

Levine and his coworkers attempted to perform an epidemiological study of fertility in male workers exposed to EDB. They compared the average number of children born to the spouses of married workers with the average number of children born to all females in the U.S., as reported by the National Center for Health Statistics.

In this study, it was assumed that the reproductive health of workers exposed to EDB was not adversely affected because the average number of children born to the spouses of the workers was similar to averages reported in the national statistics.

The major deficiencies in this study are:

- The most significant deficiency is the lack of sensitivity for detecting adverse reproductive effects.
- The investigators did not evaluate a large enough population of unexposed workers to make a comparison of fertility. Because of the lack of an adequately matched control population, this study cannot discern whether potential differences are the result of exposure to EDB or other confounding variables.

- The investigators did not consider such factors as the desire of workers to have children or use of contraceptives to control fertility. An observation that an individual has produced offspring does not exclude the possibility of serious reproductive consequences such as subtle decrease of fertility, problems in sexual performance or reduced libido.

The deficiencies in this study preclude its use to determine a measureable effect of EDB exposure on fertility. Because of these deficiencies, this study cannot be accepted as evidence for the lack of adverse reproductive effects of workers exposed to EDB.

An additional comment relates to both studies. Neither study examined the possibility of adverse reproductive effects in female workers. To adequately address the possibility of adverse effects in all workers, it is also necessary to evaluate reproductive ability in both sexes, and evaluate pregnancy outcomes of women exposed to EDB.

c. Conclusion

Two recent studies (Ter Haar 1981; Levine et al., 1981) have been sumbitted in response to the Agency's presumption in the PD 2/3 of adverse reproductive effects resulting from exposure to EDB. These studies attempt to show that there is not a significant difference between fertility of workers exposed to EDB and fertility of the general population. Because they contain numerous deficiencies, these reports do not rebut the presumption of reproductive effects as described in PD 2/3. The Agency's detailed analysis of these studies is contained in "REAG Response to Industry Rebuttals Concerning The Reproductive Risks of EDB" (REAG, 1982).

III. Revisions and Amendments to PD 2/3: Exposures and Associated Health Risks

A. Applicator Exposure

Subsequent to the publication of the PD 2/3, the Agency received substantive additional information regarding four applicator exposure situations. Therefore, the Agency has revised the original estimates of applicator exposure for preplant soil fumigation and quarantine fumigation of citrus, and completed an exposure analysis for fumigation of felled logs and the post harvest fumigation of papayas.

1. Preplant Soil Fumigation

EDB inhalation exposure of soil fumigation applicators has been reassessed based on two factors (Reinert 1982 c). First, use information, more reliable than that used in the PD 2/3, was provided to the Agency in the comments of Great Lakes Chemical Corp. (Comment #24). Second, new exposure studies for this use pattern were provided by Dow Chemical Co. in their comments on the PD 2/3 (Comment #34).

The Agency estimates that the use of certain specified types of respirators during all phases of application would reduce inhalation exposure by about 90%, at the peak efficiency of the respirators, assuming no breakdowns, malfunctions, or improper use of the equipment (dermal exposure is assumed to be insignificant compared to inhalation for this use).

Based on the new data on average air levels encountered during transfer and application, use of respirators solely during the transfer of the pesticide could possibly reduce exposure by approximately 80%. The additional data have been combined with the data used in the PD 2/3 and new averages determined as shown in Table 1.

Table 1. Data on EDB Air Levels During Transfer and Application

	PD 2/3 avg. (mg/m^3)	New data (mg/m^3)	Revised exposure (mg/m^3)
Application (open cab)	0.81*	14.6, 10.8 3.8, 0.54	1.9
Transfer (open system)	3.03**	484, 238, 36.1 27.7, 7.7	114.0

* Average of 21 data points

** Average of 2 data points

Recently, additional applicator exposure data related to the soil fumigation use of EDB has been made available to the Agency (CDFA, 1983). The levels of EDB measured in the air during application are consistent with values in Table 1. Air levels measured while loading the chemical are considerably lower than those in Table 1. This is expected because closed mixing and loading systems were employed in the CDFA study.

Potential dermal exposure to the hands was measured in this study. The results are consistent with the assumption that potential dermal exposure will be insignificant compared to potential inhalation exposure for this use pattern.

The revised respiratory exposure estimates for applicators engaged in soil fumigation using open transfer systems and open cabs are shown in Table 2.

Table 2. EDB Respiratory Exposure During Soil Fumigation

Use Site	Duration of annual exposure (hrs)*		Annual inhalation exposure (mg/year)**
	Transfer	Application	
Fruit trees	0.8	7.2	130
Tobacco	1.8	16.2	280
Peanuts	1.5	13.5	240
Pineapples***	24.5 - 43.0	220.5 - 387	303.3 - 532.4
Misc. vegetables and fruits	2.6-7.8	23.4-70.2	410-1200
Sweet potatoes	8	72	1300
Irish potatoes	8.1	72.9	1300
Cotton	2	18	310
Citrus	0.8	7.2	130

* data from Great Lakes Chemical Corp., Table II of exhibit 2 of their rebuttal package.

** dermal exposure is assumed to be insignificant compared to inhalation exposure.

*** From PD 2/3, where it was noted that this may be an overestimate of exposure for this crop, because different agricultural practices are employed in the fumigation of pineapple fields.

Sample calculation: using as an example the use site "fruit trees"; 1.2 m^3/hr (7.2 hours app./year x 1.9 mg/m^3 + 0.8 hours trans./year x 114 mg/m^3) = 125.8 mg/year.

2. Quarantine Fumigation

The Agency has received information from the Florida Department of Citrus demonstrating that work at citrus fumigation stations and warehouses should not be classified as "heavy activity." The breathing rate for "moderate activity" (1.2 m^3/hr) has therefore been used to revise the applicator and warehouse worker respiratory exposure calculations. The Agency has also received additional worker monitoring data from the Occupational Safety and Health Administration (OSHA, 1981) on exposure to truckers and fumigation station personnel. This information has been used by the Agency to revise exposure estimates for citrus fumigation.

The additional data have been used to revise the Agency's estimates of respiratory exposure to workers involved in quarantine fumigation. Two types of new data are utilized in the Agency's revision of respiratory exposure. The breathing rate was reduced from 1.8 m^3/hr. for heavy labor (listed in PD 2/3) to 1.2 m^3/hr. for light to moderate labor. The results are lower estimates of exposure to EDB per year. The second kind of new data is EDB worker monitoring data now available which were not available for the PD 2/3 assessment. The revised exposure estimates are presented in Table 3.

The Agency has received information from the Papaya Administrative Committee regarding the flow/work practices of papaya shippers in treating fruit with EDB (Comment #23). The Agency previously had no information on the treatment of fruit in Hawaii. The Papaya Administrative Committee states that in Hawaii, fruits are delivered to the packing houses in wooden field bins. The fruits remain in these containers through fumigation until they are hand-packed. After hot water treatment at approximately 120° for 20 minutes for partial fruit fly disinfestation and disease control, the fruits are dried and fumigated according to APHIS requirements. Following EDB fumigation, fruits are

Table 3. Revised EDB Inhalation Exposure of Workers at Citrus Fumigation Stations and at a Citrus Warehouse

Location Workers	Concentration of EDB (mg/m^3) Avg.	Number of samples	Breathing Rate (m^3/hr)[1]	Hrs/day[2]	Days/yr[3]	Avg. exposure to EDB (mg/kg/yr)[4]
Wahneta - Indoor operators	0.207	14	1.2	8	112	3.2
Ft. Pierce - Indoor operators	0.607	1	1.2	8	112	9.4
Wahneta - Outdoor operators	0.406	19	1.2	8	112	6.2
Ft. Pierce - Outdoor operators	0.280	2	1.2	8	112	4.4
Wahneta - Truckers/Station Personnel	0.048[5]	3	1.2	8	112	0.8
Ft. Pierce - Truckers/Station Personnel	1.092	1	1.2	8	112	1.4
OSHA [6] Truckers/Station Personnel	0.18	9	1.2	8	112	2.8
Wahneta - Truckers	1.93	2	1.2	0.08	112[8]	0.2
OSHA[6] Truckers (during coupling and uncoupling)	4.26	5	1.2	0.08	112[8]	0.6
OSHA[6] Truckers (on road)	0.07	5	1.2	8	112	1.1
Tampa - Forklift operators, Laborer (inside)	8.99 2.72[7] 4.75[6]	1 unknown 5	1.2 1.2 1.2	8 8 8	155[9] 155[9] 155[9]	192 58 101
Tampa - Forklift operators, Laborer (outside)	2.36 1.65[7] 2.00[6]	3 unknown 17	1.2 1.2 1.2	8 8 8	155[9] 155[9] 155[9]	50 35 42
Tampa - "Stickmen"	4.76	2	1.2	8	155[9]	101
OSHA[6] "Stickmen"	8.57	6	1.2	8	155[9]	182

[1] Assuming light activity (Spector, 1956).
[2] Hrs./day are variable depending on work load during year. Average 8 hr. work day is assumed here.
[3] Data from APHIS (1977)
[4] Assuming a 70 kg worker.
[5] Including "non-detectable" samples at level of detection (0.008 m^3).
[6] OSHA survey 1981 draft report
[7] From Florida Citrus Rebuttal
[8] Assuming trucker returns once each day
[9] Assuming 22 working days a month over the period of October 11—through May 14.

typically stored until packing time. The fruits are then culled, sized and handpacked into cardboard cartons.

The Agency has received information from the Hawaii Papaya Industry Association regarding exposure to applicators fumigating papaya with EDB (Hertlein and Hagadone, 1981). EDB concentrations were measured in the ambient air of the fumigation area. EDB levels ranged from 0.1 to 3.6 ppm; the average concentration was 0.86 ppm or 6.6 mg/m^3. The Agency has calculated an applicator exposure of 10 mg/kg/yr using the following assumptions.

- o The EDB concentration in the ambient air is representative of applicator exposure.
- o Applicators perform "light" to "moderate" work at a respiratory rate of 1.2 m^3/hr.
- o Applicators are exposed for 10 minutes per load of papayas fumigated.
- o An applicator fumigates 530 loads per year.
- o An applicator weighs 70 kg.

Sample calculation:

$6.6 \text{ mg/m}^3 \times 1.2 \text{m}^3\text{/hr} \times 88 \text{ hr/yr} \times 1/70 \text{ kg} = 10 \text{ mg/kg/yr}$

The person assigned to the job as applicator at papaya fumigation station is very often also assigned to operate a fork lift to move bins of fruit from one operation to another. Workers removing papaya from fumigation chambers would be exposed to air concentrations of EDB from 0.07 to 1.6 ppm; the average concentration was 0.54 ppm or 4.2 mg/m^3. Workers removing papaya from refrigators after fumigation would be exposed to air concentrations of EDB ranging from 0.02 to 0.53 ppm; the average concentration was 0.36 ppm or 2.8 mg/m^3 (Hertlein and

Hagadone, 1981). The Agency has calculated worker exposure of 8 mg/kg/yr and 6 mg/kg/yr, while moving bins of fruit from the fumigation chamber and refrigators, respectively (Ludvik, 1982; Saito, 1982).

Fruit sorters and packers are exposed to air concentrations of EDB ranging from 0.09 to 0.22 ppm; the average concentration was 0.14 ppm or 1.1 mg/m^3. Assuming a 60 kg woman works an 8 hour day, 5 days per week and 48 weeks per year, she would be exposed to 42 mg/kg/yr of EDB. If the woman works an 8 hour day, 3 days per week and 50 weeks per year, she would be exposed to 26 mg/kg/year (Ludvik, 1982; Saito, 1982).

A summary of all applicator exposure estimates is presented in Table 4.

Table 4. Summary Table of PD 4 Applicator Exposure Estimates Compared with Exposures from PD 2/3

		mg/kg/year 1/	
Workers at Citrus Fumigation Stations In Fla. 3/ (inhalation)		PD 2/3	PD 4
W - indoor operators 4/		4.8	3.2
FP - indoor operators		14	9.4
W - outdoor operators		9.4	6.2
FP - outdoor operators		6.5	4.4
W - truckers/station personnel		1.1	0.8
FP - truckers/station personnel		2.1	1.4
OSHA - truckers/station personnel		—	2.8
W - truckers		0.4	0.2
OSHA - truckers (during coupling)		—	0.6
OSHA - truckers (on road)		—	1.1
T - forklift operators/laborers (inside)		287	192
OSHA - forklift operators/laborers (inside)		—	101
T - forklift operators/laborers (outside)		75.3	50
OSHA - forklift operators/laborers (outside)		—	42
T - "stickmen"		151.8	101
OSHA - "stickmen"		—	182
Hawaiian Papaya			
Applicator		—	10
Packer/Sorter		—	26-42
Indoor laborer		—	14
Felled Log 2/ Applicators		PD 2/3	PD 4
	dermal	—	69
	inhalation	—	24

Table 4 Continued. Summary Table of PD 4 Applicator Exposure Estimates Compared with Exposures from PD 2/3

	mg/kg/year 1/	
	PD 2/3	PD 4
Soil Fumigation: Applicators (inhalation)		
tree site	0.01	1.9
tabacco	0.18 - 0.44	4.0
peanuts	0.21	3.4
Misc. fruits & vegetables	0.18 - 0.92	5.9 - 17
sweet potatoes	0.034 - 0.053	19
Irish potatoes	0.07 - 0.12	19
cotton	0.35 - 1.8	4.4
citrus (preplant)	0.44 - 0.56	1.9
pineapples	4.3 - 7.6	4.3 - 7.6
citrus (barrier)	7.4	7.4
Spot treatment		
applicator	4.3 - 59.3	4.3 -59.3
mill worker	9.4 - 10.9	9.4 - 10.9

1/ body weight = 60 kg for packers/sorters for papaya, 70 kg otherwise.

2/ for this use pattern, the number of years an individual would work as a fumigator is estimated to be 1.25 years/lifetime (4).

3/ exposure stidies for workers involved in citrus fumigation in California have been carried out (18,32), and these studies have been evaluated (33, 34). However, the use information (annual and lifetime durations of exposure) necessary for exposure assessment is unavailable.

4/ W = Wahneta; FP = Ft. Pierce; T = Tampa

3. Felled Log Fumigation

In the PD 2/3, the Agency reported that there were no data available on EDB exposure to felled log applicators. The Agency has since obtained data on EDB air concentration during felled log application (USDA, 1973), use rate information (Day, 1981a and EPA, 1981), and surrogate data on dermal exposure to 2,4,5-T resulting from a similar application method (Lavy *et al.* , 1980). The Agency has estimated EDB exposure to felled log applicators based on these data. The exposure estimates assume a breathing rate of 1.2 m^3/hr. for moderate activity, and that the average applicator weighs 70 kg. The results are summarized in Table 5 below.

Table 5. Estimated EDB Exposure to Felled Log Applicator

	mg/hr.	mg/day	mg/yr.	mg/kg/lifetime*
Dermal	75	300	4800	86
Respiratory	26	104	1664	30

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* 1.25 years/lifetime spent in application (Ludvik, 1982). In using these surrogate data to estimate EDB exposures, the Agency recognizes that questions have been raised regarding whether the Lavy patch data adequately represent the amount of dermal exposure to the applicators. However, at this time, the Lavy data are the best data available to the Agency which can be extrapolated for this particular use pattern. Therefore, the Agency is using these data with the understanding that any EDB exposure assessment, based on these data, is subject to the same qualifications and limitations as the original Lavy data.

B. Applicator Risk

The Agency's Carcinogen Assessment Group has estimated the cancer risks associated with occupational exposure to EDB in quarantine fumigation of citrus, quarantine fumigation of Hawaiian papayas, felled log fumigation, soil fumigation, and spot fumigation of grain milling machinery. Risk figures were derived using the original linear non-threshold model discussed in the PD 2/3. These risk figures are based on a rat inhalation study (McGaughy, 1982) and are presented in Table 6.

The Agency calculated risk figures for applicator by assuming that the major route of applicator exposure will be via inhalation. For the felled log treatment the Agency does assume that dermal exposure could be a significant route of exposure. In addition to the exposure received on the job, workers will also be exposed to a similar amount of EDB in their diet as will the general public. Some workers, particularly those involved in soil fumigation, may also be exposed to contaminated drinking water.

Proper use of respirators, operating at peak efficiency, during all phases of application could reduce inhalation exposure by about 90%, and could result in similar reduction in increased cancer risk. It should be noted that this estimate assumes that that the respirator is in good repair, properly fitted, and worn at all times that an exposure potential exists. The latter consideration is particularly important because some tasks e.g. packing and sorting papayas and soil injection, could result in low levels of EDB for approximately 8 hours per day. Physiological and psychological limitations make wearing a respirator for extended periods highly unlikely (NIOSH, 1976).

Table 6. Revised Cancer Risk Due to Occupational Inhalation of EDB

Exposed group	Range of exposure (mg/kg/day)	Lifetime probability estimates	No. of workers exposed
Soil injection (6)			
farmer/applicator	$3.0 \times 10^{-3} - 3.0 \times 10^{-2}$	$3.5 \times 10^{-3} - 3.5 \times 10^{-2}$	14,000
Quarantine fumigation (6) (Florida citrus)			
station indoor operator	$5.0 \times 10^{-3} - 1.5 \times 10^{-2}$	$5.9 \times 10^{-3} - 1.7 \times 10^{-2}$	11[1/]
station outdoor operator	$6.9 \times 10^{-3} - 9.7 \times 10^{-3}$	$8.1 \times 10^{-3} - 1.1 \times 10^{-2}$	10[1/]
trucker/station personnel	$3.1 \times 10^{-4} - 4.3 \times 10^{-3}$	$3.6 \times 10^{-4} - 5.0 \times 10^{-3}$	10[1/]
warehouse indoor laborer	$1.6 \times 10^{-1} - 3.0 \times 10^{-1}$	$1.7 \times 10^{-1} - 3.0 \times 10^{-1}$	4-1-
warehouse outdoor laborer	$6.6 \times 10^{-2} - 7.8 \times 10^{-2}$	$7.4 \times 10^{-2} - 8.7 \times 10^{-2}$	4-10
warehouse stickman	$1.6 \times 10^{-1} - 2.8 \times 10^{-1}$	$1.7 \times 10^{-1} - 2.8 \times 10^{-1}$	4-10
Quarantine Fumigation (6) (Hawaii papaya)			
applicator	1.5×10^{-2}	1.7×10^{-2}	5[3/]
sorter/packer	$4.1 \times 10^{-2} - 6.9 \times 10^{-2}$	$4.7 \times 10^{-2} - 7.8 \times 10^{-2}$	unknown
indoor laborer	$9.1 \times 10^{-3} - 1.3 \times 10^{-2}$	$1.0 \times 10^{-2} - 1.4 \times 10^{-2}$	unknown
Spot fumigation (4)(6)			
applicator	$6.6 \times 10^{-3} - 9.1 \times 10^{-2}$	$7.7 \times 10^{-3} - 1.0 \times 10^{-1}$	2400 - 6000
millworker	$1.5 \times 10^{-2} - 1.7 \times 10^{-2}$	$1.7 \times 10^{-2} - 2.0 \times 10^{-2}$	16,000
Felled log treatment			
Inhalation	1.2×10^{-3}	1.4×10^{-3}	unknown
dermal	$3.4 \times 10-3$	$8.4 \times 10-2$	
total		9.5×10^{-2} (5)	

(1) Assumed that 31 federal and state employees are evenly distributed. (Mittelman 1980)
(2) Per warehouse, Seasonal variation. Assumed that 12-38 laborers per warehouse are evenly distributed (Mittelman 1980)
(3) Ludvik 1982c
(4) Figures have not been revised - no additional data received since publication of EDB PD 2/3.
(5) Based on an inhalation model, assuming 100% absorption and 1.25 years of application exposure/lifetime.
(6) Exposure is without proper use of respirator.

C. Dietary Exposure from Quarantine Fumigation

The Agency has modified the PD 2/3 estimates of the dietary exposure resulting from fumigation of citrus and tropical fruit in three significant ways. First, the citrus food factor pertaining to the consumption of fresh fruit has been used, rather than the factor for all citrus (both fresh and processed). This change has been made because EDB is used only on fruit destined for the fresh market. Second, residue data on the edible portions of citrus and tropical fruit has been used, rather than data on the whole fruit. Use of whole fruit in estimating exposure tends to exaggerate true dietary exposure, because EDB residues tend to concentrate in the peel and seeds - portions of the fruit which are not typically consumed. Some consumers of treated citrus do consume portions of the citrus peal; dietary exposures to those persons would be underestimated.

Further, in response to a recommendation by the FIFRA Scientific Advisory Panel, the Agency has used additional data that were not previously available for residues of EDB in citrus and tropical fruit. A recent study by the California Department of Food and Agriculture (CDFA) has been used (Maddy *et al.*, 1981a). In this study, samples of fumigated fruit originating in Florida, Texas and Mexico were randomly taken from wholesale and retail markets in California and analyzed for EDB. Normal commercial practices, such as typical time intervals from fumigation to the store shelves, were assumed. Third, more accurate estimates of the percent of fumigated fresh fruit on the grocery shelves in various geographical areas have been used rather than assuming a uniform national average treatment of 2.6% of fresh citrus and 72% of fresh tropical fruit. This change has been made because certain states, such as California, require fumigation of most incoming citrus and tropical fruit, while other states do not require fumigation of any fruit. Thus, California consumption of fumigated fruit exceeds the national average. We expect dietary exposures, calculated for California, to also be representative of other locales which require fumigation. These areas include Texas, Arizona and New Mexico.

In addition, data collected by USDA's Agricultural Marketing Service indicate that most fresh citrus imported from Mexico (all of which is treated with EDB), is shipped to the Southwestern and Western U.S. Although data specifically identifying the amount of citrus shipped to the individual states is unavailable, the Agency believes that this contribution would increase dietary exposures in the Southwestern and Western U.S.

If such data were available, the estimate of the total volume of EDB treated citrus consumed in California would be larger, i.e., it would include both domestically produced EDB-treated citrus and imported EDB-treated citrus. The USDA data further indicates that a small volume of the citrus shipped from Florida to California is ultimately shipped to Hawaii and consumed there. Although exact figures are not available, this will result in a slight overestimate of the California-consumed citrus treated with EDB. The Agency does not expect the proportion of EDB-treated citrus consumed in Hawaii to differ significantly from the national average (Zygadlo, 1982b). A summary of the data collected by CFDA prior to 1982 on residues of EDB in the edible portions of citrus and tropical fruits is shown in Table 7.

Table 7. Residue Levels in Edible Portion of Fruit (ppm) [1]

	Number of Samples Analyzed	Range of Values Observed[2]	Mean [4]
Grapefruit	24	ND - 0.326	0.051
Limes	10	ND - 0.01	0.0013
Papaya[3]	35	ND - 0.102	0.011
Mangos	27	0.002 - 0.27	0.057
Lemons	3	ND	ND
Oranges	6	ND - 0.24	0.048

(1) Source: Maddy, K.T. et al ., CDFA Report HS-959, Oct. 21, 1981b.
(2) Limit of detection of analytical method is 2 ppb.
(3) Wholesale and retail samples combined.
(4) Non-detectable samples were assigned a value of zero.

More recent data (CFDA, June 2, 1983) has shown residues of EDB in fruit can be even higher:

Commodity	Origin	Date Sampled	EDB Residues (PPM)
			Pulp
Grapefruit	Texas	2/2/82	0.28
Grapefruit	Texas	2/4/82	0.21
Oranges	Texas	1/23/82	0.88

These data indicate that there may be significant seasonal variations in the levels of EDB residues in fumigated citrus. Three composite samples, shown above, (2 grapefruit and one orange which were fumigated in Texas and collected by CDFA in California in January and February, 1982) showed signficantly higher levels of EDB than the CDFA samples used for the dietary exposure assessment. The residue levels used in the dietary risk assessment in this document were obtained from fruit which were collected in September and October of 1981.

The average lower temperature in the winter months are likely to be responsible, at least in part for the observed difference in residue levels (Maddy, K.T. personal communication to J.C. Reinert, EPA, August 12, 1983). In addition, the Agency received a preliminary report from the Agricultural Research Service, USDA and the Florida Department of Citrus on factors affecting residue levels in grapefruit fumigated with EDB (USDA, 1983). These reports demonstrated that at the current treatment rate both time and temperature are factors in reducing EDB residue levels in the edible portion of grapefruit.

Although elevated storage temperatures resulted in lowered EDB residues, temperature was not as significant as time in reducing EDB levels (USDA, 1983). Because this report was a controlled study, not a monitoring study of fruit residues in commerce - it is not useful for estimating dietary levels. The results, however, are not inconsistent with the exposure data for California used in this document.)

Arizona, California, New Mexico and Texas require fumigation of all fresh citrus shipments from Florida. Additionally, Arizona, California and New Mexico require fumigation of fresh citrus shipments from Texas. However, because of the success Texas has had with their Mexican fruit fly erradication program, only about 20% of citrus shipped from Texas to these states had to be fumigated this past growing season. Dietary exposure estimates for domestic citrus were developed for California based on 1982 historical Texas and Florida citrus fruit shipment data (Zygadlo, 1982a). This information indicated that 17% of fresh oranges, 35% of fresh grapefruit and 4.4% of other fresh citrus consumed in California were fumigated with EDB. Since the 1982 data were developed, the California dietary exposure estimates may need to be reduced due to the success of the Mexican fruit fly certification program in Texas. Information submitted to the Agency from CDFA indicate that, a smaller percentage of citrus consumed in California may be fumigated, than indicated in the 1982 estimates, but, CDFA estimates have not yet been confirmed. The dietary burden to California consumers is shown in Table 8 using the original 1982 estimates.

Table 8. EDB Dietary Burden from Quarantine Citrus Fumigation

		in California		
Fruit	mean residue level (ppm)	% of diet fresh fruit	% of fresh fruit treated [5]	dietary burden (mg/kg body weight/day) [3]
Oranges	0.048	1.35	17	2.75×10^{-6}
Grapefruit	0.051	0.82	35	3.66×10^{-6}
Lemons and limes[2]	0.001	0.17	4.4	1.86×10^{-9}
Other citrus	0.025	0.48	4.4[1]	1.32×10^{-7}
			Total	6.54×10^{-6} [4]

(1) Assumed to be the same as for "miscellaneous citrus"

(2) The Agency has conflicting information on the percent of lemons and limes which are fumigated with EDB. Their estimated contribution to the dietary burden is insignificant regardless.

(3) Sample calculation using "oranges" as an example: Dietary burden = (0.048 mg/kg diet x (1.5 kg food consumed/day) x (1/60 kg) x 0.0135 [fraction of diet which is fresh oranges] x 0.17 [fraction of consumed fruit which has been treated] = 2.75 mg. EDB/kg.b.w./day.

(4) If Mexican Citrus is included, the addition to dietary exposure (Reinert, 1982, DB = 0.411×10^{-6} mg/kg/day) to the above total (6.54×10^{-6} mg/kg/day) yields a grant total of 6.95×10^{-6} mg/kg/day.

(5) Based on the 1982 estimate discussed on the previous page.

In states which do not require incoming domestic shipments of fruit to be fumigated with EDB, dietary exposure to EDB will still exist from consumption of fumigated imported Mexican citrus and imported tropical fruits. Mexican citrus accounts for 1.38% of the overall fresh market in the U.S. Fumigated tropical fruits account for 72% of the fresh tropical fruit market in the U.S. In the absence of specific data, the Agency will assume that this fruit is uniformly distributed across the country.

Table 9 compares the PD 2/3 and PD 4 estimates of the total dietary burden which results from the use of EDB as a post-harvest fumigant of citrus.

Table 9. Dietary Burden Comparison: Citrus*
(mg/kg body weight/day)

PD 2/3	1.2×10^{-5}
PD 4 (non-CA residents)	4.1×10^{-7}
PD 4 (CA residents)	6.9×10^{-6}

*Including the contribution from Mexican citrus and using the 1982 estimates of percentage of fresh fruit treated.

The calculations below present the dietary burden estimates for a "tropical fruit eaters". It is assumed that "tropical fruit eaters" consume 12 fruits/year. These individuals constitute a small portion of the U.S. population. Since the average EDB residue contamination has been determined to be 0.031 ppm (=0.031 mg EDB/kg fruit, the average residue level for the all papaya and orange samples) (Reinert, 1982) then the dietary burden for tropical fruit (mangos and papayas) can be estimated as follows:

Example Dietary Burden Calculation for Tropical Fruits

$$DB = 12 \text{ fruits/yr.} \times \frac{1 \text{ yr.}}{365 \text{ days}} \times \frac{0.25 \text{ kg.}^{*}}{\text{fruit}} \times \frac{0.031 \text{ mg}}{\text{kg.}}$$

$$\times \frac{1}{60 \text{ kg b.w.}}$$

$DB = 4.25 \times 10^{-6}$ mg EDB/kg/b.w./day

* 0.25 kg, the average weight of the edible portion of papayas and mangos.

D. Contamination of Wheat By-Products from Bulk Grain and Spot Treatment of Grain Milling Machinery with EDB

Grain Fumigation

On February 27, 1980 a re-evaluation of the total dietary burden of EDB with respect to the post-harvest grain uses was submitted to Special Pesticide Review Division (J.W. Holder, RCB ro R. Johnson SPRD). In that review it was estimated that the "probable" residue level for EDB in wheat bread derived from grain fumigated after harvest with EDB would be 0.07 ppb (.008 ppb from on-farm and 0.062 ppb from off-farm uses). It was also estimated that the "realistic worst case" level which assumed that the grain would be treated at the maximum rate, not mixed with untreated wheat (no dilution), and minimum commercial transit times (minimum opportunity for dissipation of residues) would be 31 ppb EDB (7.2 ppb from on-farm and 23.4 ppb from off-farm uses). A third estimate using a mass-balance approach yielded an estimated contamination level of 87 ppb.

Since the above modeling estimates were made, the results of an investigation of actual residues in wheat flour from commerce, and biscuits produced from that flour has been published (D. Rains and J. Holder, J.O.A.C 64, (5), 1981, pp 1252-1254). The flour analyzed in the investigation were geographically representative of cities throughout the continental U.S. All but one of the twenty-two flour samples contained detectable levels of EDB (more than 0.5 ppb). The reported levels in flour ranged from ND to 4,200 ppb. Twenty of the twenty two biscuit samples baked from the flour also contained detectable levels of EDB. The levels reported to have survived the baking process ranged from ND to 260 ppb and averaged 35.7 ppb.

If these data are indicative of the actual residues in U.S. finished wheat products, they indicate that the "probable" case underestimated EDB levels, and that actual levels may approach the "realistic worst case" level of 31 ppb.

Therefore, it is now the Agency's judgement that the "realistic worst case" level is the more appropriate estimate for the dietary burden from bulk grain uses, rather than the "probable case" estimate used in the PD 2/3. Thus, 31 ppb EDB in grain products is equivalent to a dietary burden of 8.0×10^{-5} mg EDB/ks/day for a 60 kg person consuming 1500g of total food per day.

Spot Fumigation

As discussed previously in PD 1 and PD 2/3, the available residue data reflecting the levels of EDB in grain products processed in mills spot-treated with EDB are of limited value. All of the available studies involved wheat with significant levels of EDB before milling.

However, even though these data are not adequate to determine with certainty the residue levels expected in much of the flour milled during the four weeks between treatments, they do show that spot fumigation does contribute significant residue levels of EDB based on a time-weighted average over the period of the month between treatments.

In the PD 2/3, the estimate for the residue levels contributed by spot fumigation was based on a 1978 Litton Bionetics study for Ferguson Fumigants, Inc. The estimate of 68 ppb in flour (based on a time-weighted-average over four weeks) made no correction for the levels of EDB in the incoming wheat grain because the exact portion of these EDB residues that transferred to the flour (and thus to wheat by-products) was unknown, and because several investigators have reported that the majority of these are retained by other milling fractions (such as bran, offal, shorts, germ, etc.). However, even if it is assumed that all the EDB residues detected in the incoming wheat were concentrated in the finished flour, the available data still indicate that the spot fumigation contributed significant residues of EDB to the flour. It has been reported that EDB levels in the incoming grain ranged between 30 to 50 ppb. Assuming that all the EDB was concentrated in the finished flour, the resulting levels would be 43 to 71 ppb in flour. If these calculated background levels are subtracted from the levels actually reported for flour (which ranged from 54 to 1,410 ppb), the calculated time-weighted-average residue level would be 34 ppb. Thus, the 34 ppb appears to be the minumum net increase, over time between fumigations, that results in wheat flour from spot fumigation.

Accordingly, it continues to be the Agency's judgement that the spot fumigation use contributes significantly to the dietary burden of EDB, and that 3 ppb in finished baked products (based on 68 ppb in flour) is a reasonable estimate of the expected dietary burden. Thus, 3 ppb EDB in grain products is equivalent to a dietary burden of 5.8×10^{-6}mg EDB/kg. b.w./day for a 60kg person consuming 1500g of food/day. This is calculated from the worst case (J. Holder,1980) DB = 7.7×10^{-6} times 3/4, where 3/4 of the mills are estimated to use EDB for spot fumigation use.

The Agency is continuing to monitor for residues of EDB in grain, flour, and finished baked goods. This monitoring is being undertaken in coordinated interagency efforts with USDA and the Food and Drug Administration. In addition to flour and baked goods, milk, and meats including beef, poultry and pork are being sampled. The Agency will continue to evaluate these data to establish a more complete understanding of the extent of hazard to public health resulting from fumigation of stored grains and spot fumigation of grain milling machinery. If the extent of the hazard posed by either or both of these uses of EDB becomes more clearly delineated and defensible, the Agency will consider emergency suspensions for these uses.

E. Ground Water Contamination

As of September 16, 1983, EDB has been found in water from approximately 114 different wells in four states. In all cases, EDB use as a soil fumigant is an extremely likely cause or is at least a possible cause of the contamination. A summary of the monitoring data follows. A discussion of the persistence and transport of EDB follows after the monitoring summary, along with a discussion of the possible significance of gasoline leakage to the contamination in ground water.

1. Monitoring Results

In 1980, the EPA helped design and sponsor a ground water contamination study by the California Department of Food and Agriculture. The object of the study was to determine the extent and mechanism of ground water contamination by four pesticides in certain areas of California. EDB was one of the chemicals selected, and the draft report* indicated that two wells out of over two hundred sampled** were contaminated with 0.1 ppb and 0.2 ppb EDB (Zalkin, et al., in progress). More importantly, EDB was found at concentrations between 0.1 and 31 ppb in the soil at depths greater than 20 feet, moving down to ground water. Since these preliminary reports were received in spring, 1983, EDB has been found in ground water in 16 different counties in the states of California, Florida, Georgia, and Hawaii. The levels reported vary between 0.02 ppb and ca. 300 ppb, and are typically between 0.05 and 5 ppb. The results are summarized in Table 10, and a state-by-state discussion follows.

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* The final report is being written in three volumes which are presently in various stages of peer review.

** Not all of the wells sampled were near EDB use sites.

Table 10 EDB Ground Water Contamination Known or Suspected to be Due to Agricultural Use

States	No. of Counties	No. of Positives (approx.)	Typical Positives (ppb)
California	5	18	0.1-2.0
Florida	9	86	1.0-15.0
Georgia	1	6	0.1-10.0
Hawaii	1	4	0.02-0.1
Total	16	114	0.05 - 5.0

In general, the detectable levels of EDB cited above have been confirmed by two gas chromatography (gc) methods and/or gc-mass spectrometry when possible.

a. California

The monitoring has been done by the Department of Food and Agriculture, the State Water Resources Control Board, and the Department of Health Services, with some assistance from EPA. The 15 to 20 positives have been in the San Joaquin Valley area. Approximately two small community drinking water supplies have been contaminated. Probably 250 to 300 water samples have been negative for EDB over the last four years, in California, but for many of these negatives:

1) it is not known whether EDB had been used near (ca. 1/4 mile) the wells;
2) the number of years of EDB use have often not been known;
3) and, the minimum detection limit at the time of sampling was higher, making it more difficult to detect low levels of EDB than it now is.

State agriculture and health officials have concluded that in most, if not all, cases contamination is likely due to EDB use as a soil fumigant. (A single positive in Solano County has not been included in this assessment because it may have been due to poor industrial practice.)

b. Florida

Two different areas of Florida have been sampled since mid-1983 and both areas contain ground water contaminated with EDB. Those areas are an eight county citrus growing region in central Florida, and the soybeans/peanuts area of Jackson County, in the panhandle.

As of early September, 1983, 86 out of 334 wells sampled contain detectable levels (> 20 parts per trillion) of EDB; 75 of these 86 positives contain EDB concentrations greater than the level 0.1 ppb (Bigler, 1983), which the state has selected as an interim action level. The contamination in the central Florida area was most likely due to citrus buffer zone applications done by the state agriculture department; the panhandle contamination was most likely due to EDB soil fumigation of soybean and/or peanut fields.

The Florida monitoring program is a collaborative effort between the Departments of Environmental Regulation, Health and Rehabilitative Services, and Agriculture. They have been sampling wells within 300 ft. of use sites, and intend to sample a total of 1000 or more wells. All sampling and analysis has been done since approximately mid-summer, 1983. As a result of this monitoring program, on September 16 the State of Florida temporarily suspended the soil fumigation use of EDB.

c. Georgia

EPA scientists were notified in June, 1982, by EDB registrants that three wells were contaminated with EDB at levels as high as 100 ppb (an irrigation well) in Seminole County. After the registrants failed to conduct any further monitoring, the EPA and the USGS, in cooperation with the county extension agent, initiated and completed a reconnaisance study of the area in late summer, 1983. Nineteen wells and one surface water sample were analyzed, and six wells were found to be contaminated with between 0.03 and 11.8 ppb EDB. In addition, soil cores from one hole drilled to the producing aquifer contained EDB below 20 feet. The pesticide was known to be used throughout most of the study site; apparently, the uses began after EPA suspended DBCP use in the fall of 1979.

The report (Jovanovich and Cohen) is in review. Conclusions in this report are that the contamination did not result from a single point source and was due to agriucultural use of EDB.

d. Hawaii

Based on the preliminary results from California, in June, 1983, the Agency requested that the State of Hawaii monitor soil and ground water for EDB. Staff from the Departments of Health and Agriculture, Castle and Cooke (Dole), and others, immediately began an active monitoring program (Wong, et al., in progress).

As of September 1983, most, if not all, community water supplies within one half mile of EDB use sites have been sampled and analyzed for EDB contamination. Thus over 100 different drinking water wells have been analyzed for EDB between June and September. To date, one site has contained EDB contaminated ground water - the four wells in the Waipahu well field in south cental Oahu. The levels in all four wells range between 0.02 and 0.10 ppb. EDB has been used on pineapple fields near the Waipahu wells.

Soil cores were taken from five Oahu pineapple fields from depths as great as 60 feet. Three holes were drilled in each field, for a total of 15 holes. EPA has received partial data on at least 9 of those holes. The data analyzed thus far show that EDB is present in soil cores down to the 20 to 30 ft. range. However, a closer examination of the data indicates that the soil core samples were most likely contaminated during drilling. EPA scientists cannot say with certainty what portion of the positive results was due to slow leaching through the soil profile or what protion was due to contamination during the drilling process. However, it is likely that accidental contamination was a significant contributing factor. Thus the soil core results neither support nor refute the hypothesis that the four wells were contaminated through soil fumigation and leaching to ground water. A brief description of south central Oahu's volcanic soil follows, along with a concluding statement about the problem.

Most of the organic matter, which tends to bind neutral organic compounds such as EDB, is confined to the top few feet of soil, with a heavy amount of clay (ca. 80%) throughout much of the soil profile (Green, 1983). The flow rate of water through the top few feet can increase significantly during a rainstorm, and is relatively fast, while the underlying inert clays and saprolite have slower, steadier hydraulic conductivity (Green, 1983; Eyre, 1983). This material between the fresh basalt and the top soil has been found to have practically zero adsorptive capacity for DBCP and certain herbicides (Green, 1983).

Based on this description and the persistence and transport discussion below, a picture emerges of the probable fate of EDB in a typical volcanic soil. Within several weeks of application, the pesticide leaches down into and diffuses throughout the top couple of feet of soil. During and after this time, degradation may occur, to a possibly significant extent. There is likely a significant amount of sorption to the soil, which is decreased during and/or after a rainfall event. This region of EDB sorption could serve as a 'reservoir' of EDB which could then leach in low and nonsteady amounts into and through the underlying low organic clays, saprolite, and fissured basalt. Little if any sorption would occur in this zone. Therefore, no "reservoirs' of EDB could be built up (as in the top soil) and the EDB would be present in the water phase. From this point, leaching to the aquifer could occur quickly with significant dilution occurring along the way. Therefore intermittent contamination of Oahu's basalt aquifer will likely occur in unpredictable, although probably low concentrations if continued EDB use is allowed. The term "low" in this context means concentrations not exceeding a couple of hundred parts per trillion.

2. Environmental Persistance and Transport Studies

EDB has a water solubility of approximately 4500 ppm and a room temperature vapor pressure of 11 torr. Thus it would tend to be mobile in both air and water. It diffuses in soils (Thomason and McKenry, 1974) and does not appear to sorb well to soils relative to other neutral organic chemicals (e.g., Chiou, et al., 1979). Therefore EDB is very mobile in the subsurface environment.

Not much is known about EDB's persistence, but the Agency expects it to be stable to photolysis in sunlight. EPA recently began a hydrolysis study (Jungclauss, et al., in progress). Preliminary indications are that its half-life at 20°C (a likely ground water temperature in a southern climate) is greater than one year under neutral conditions* and it may be as long as a couple of dozen years. The study should be completed in November, 1983. Cohen, et al. (1983) have stated that one of the criteria for determining that a pesticide may be a potential ground water contaminant is a hydrolysis half-life of greater than ca. 6 months; thus EDB meets this criterion.

There are two indications that EDB can degrade in soils. Castro and Belser (1968) demonstrated that EDB was degraded to ethylene and bromide ions under optimal conditions in a California agricultural soil. However, even in the same soil, the halflives in different experiments varied tremendously from ca. 2 weeks to ca. 18 weeks. According to Cohen, et. al., (1983) the soil half-life criterion for potential ground water contamination is a half-life of greater than ca. 2-3 weeks. Thus EDB meets this criterion as well. Also, high levels of bromide ions have been detected in the perch water aquifer under the site of a several hundred gallon EDB spill in 1977 on Oahu (Mink, 1981). This indicates breakdown of EDB to an unknown extent in a three year period.

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* A likely hydrolysis product is vinyl bromide, a possible carcinogen.

3. Leakage from Underground Fuel Tanks

Underground fuel storage tanks are known to leak, and this leakage can be predicted (Rogers, 1983). EDB has been used for several decades as a lead scavenger in gasoline and aviation fuel. EDB constitutes approximately 0.03% by weight of leaded gasoline, assuming 1.1 gm lead/gallon of gas, and 17.86% and 63% are the percentages of EDB and tetraethyl lead in the tetraethyl lead mixture, respectively. Thus, there is some possibility that EDB could contaminate ground water through leakage of underground fuel storage tanks.

This potential for EDB to contaminate ground water from gasoline losses should be examined on a relative basis. The Agency estimates that over 20 million pounds of the pesticide EDB are applied to soil in the U.S. annually. To have an equivalent loading to soil from losses of gasoline there would have to be approximately 10 billion gallons lost directly to the soil every year. This rough calculation is an overestimate which ignores surface and subsurface attenuation of EDB. However, even if the EDB applied to the surface were attenuated 10 times as much as the EDB which could leak from subsurface gasoline storage tanks, the equivalent loading to the soil would still require a nationwide annual leakage of 1 billion gallons of gasoline.

Although gasoline is one of the more frequently reported contaminants of wells, EPA has not seen any data so far which demonstrates that the contamination described in section 1 above was due to this phenomenon. EPA scientists would expect that any wells contaminated by this mechanism would also contain ethylene dichloride (EDC), which is also a lead scavenger in gasoline (Johns, 1976). Thus EDC would be a good chemical marker for this contamination source.

F. Dietary Cancer Risk Equation

The CAG has revised the estimates of cancer risks associated with EDB residues in the diet. This revision was made to utilize all of the information collected in the experiment, particularly the effect for partial lifetime exposure at a given dose (Weisburger, 1977). The model developed by the CAG is essentially the one-hit model with "Weibull" timing (CAG, 1982). This model fits the observed data well, it is consistent with the biological hypothesis of direct acting genotoxic agents, and it permits a direct estimate of the effect of partial lifetime exposure to be made. The model takes the form:

$$P(t,d) = 1-e^{-x}$$

where: $x = (1.02 \times 10^{-13}) \times d \times W_m^{1/3}[(t-s)^{7.6}-(t-f)^{7.6}]$

W_m = average weight of the individual from age f to s (in kg)

s = age at start of exposure (years)

f = age at end of exposure (years)

d = mg/kg/day exposure from age s to f

t = age at end of observation period (years).

For a lifetime exposure, $W_m = 60$kg., $s = 0$, $f = t = 70$ yrs. of age, the above equation has the form $P(d) = 1 - e^{-41d}$. It should be noted that this lifetime risk equation is different from the risk equation used for the PD 2/3.

G. Dietary Cancer Risks

1) Dietary Risks to the Average Consumer

The dietary burdens (DB) for EDB uses and the cancer risks for the average consumer estimated in PD 2/3 are reproduced in Table 11. The dietary burden for soil incorporation (food only, not from leaching into ground water) remains the same as PD 2/3 with the resultant risk being different due to the use of a different and improved model to estimate risk. The estimate of bulk grain dietary burden has been increased significantly (for discussion of dietary burdens see Section D), and therefore, the risks for the average U.S. consumer from this use also increases significantly. The estimate for additional cancer risk die to bulk grain fumigation is now 3.3 x 10^{-3}. This estimated risk from the bulk grain use constitutes a majority (approximate 85%) of the known dietary risks from EDB.

The spot use of EDB on grain milling machinery has been estimated to have the same time-weighted average EDB residues (from treatment to treatment) in wheat flour and baked wheat products as in PD 2/3. The cancer risk estimate for spot fumigation has been increased to 2.4 x 10^{-4}. States not requiring quarantine EDB fumigations still have contributions from EDB-treated imported fruit, e.g. from Mexico. It was assumed these imported fruits could be uniformly distributed for fresh market consumption throughout the U.S. The tropical fruit.

are assumed to be 100% treated, and distributed throughout the U.S. The dietary burden for tropical fruit is also estimated (Table 11, footnote 3). Both of these contributions of EDB are less than those in states (e.g. California), which do require quarantine fumigation of fruit from Florida. It is estimated that the risk to an average individual (60 kg, consuming 1.5 kg food/day) in those states requiring EDB quarantine fumigation would be 2.4×10^{-4} from fresh citrus consumption.

The drinking water cancer risk are summarized in the following section (Section H).

Table 11. Comparison of the PD 2/3 and PD # 4 Dietary Burdens and Cancer Risks from EDB to the Average U.S. Consumer

Fumigation Use	EDB PD 2/3 Dietary Burden (mg.EDB/kg. b.w./day)	EDB Lifetime Cancer Risk (PD 2/3)	EDB PD 4 Dietary Burden (mg.EDB/kg. b.w./day)	EDB Lifetime Cancer Risk 4/ (PD 4)
1. Soil Incorporation -	2.60×10^{-7}	5.6×10^{-5}	2.60×10^{-7} 1/	1.1×10^{-5}
2. Wheat Grain -	1.81×10^{-7}	2.6×10^{-6}	8.00×10^{-5} 2/	3.3×10^{-3}
(bulk fumigation)				
3. Spot (wheat grain - milling machinery)	3.29×10^{-6}	5.1×10^{-5}	5.80×10^{-6} 5/	2.4×10^{-4}
4. Fruit (quarantine fumigation, bulk)				
in states not requiring fumigation				
citrus -	—	—	4.11×10^{-7}	1.7×10^{-5}
tropical -	—	—	4.25×10^{-6} 3/	1.7×10^{-4}
in states requiring fumigation				
citrus -	—	—	6.8×10^{-6} (See table 8 & 9)	2.8×10^{-4}
in entire U.S. population				
citrus -	1.09×10^{-5}	2.1×10^{-4}	—	—
tropical -	1.70×10^{-6}	3.2×10^{-5}	—	—

Footnotes to Table 11 on next page

Footnotes for Table 11

(1) No residues found at a detection limit of 1 ppb EDB. Assumption that EDB residues can occur at 1 ppb. DB = (1 x 10^{-9}, residue level) x (1.5 x 10^{6} mg food consumed/day) x (0.1038, food factor for wheat) x (1/60 kg, body weight for "average U.S. consumer") = 2.6 x 10^{-6} mg/kg/day.

(2) Dietary burden increased significantly from the PD 2/3 (Table 22, Probable Case Estimates of DB) See text for rationale for estimating EDB dietary burdens in PD 4 in accordance with the Realistic Worst Case proposed in the report by J. Holder, 2/27/80.

(3) Dietary burden for a "tropical fruit eater": DB = 12 fruits/yr x 1 yr/365 days x 0.25 kg /fruit x 0.031 mg EDB/kg fruit x 1/60 kg body weight. Assumed a rate of 12 fruits/yr and an average between a papaya and a mangoe is 0.25 kg/fruit.

(4) Lifetime risks for an average person (eats 1500 g food/day and weighs 60 kg) for a lifetime of exposure and observation for cancer were calculated by the equation $P = 1 - e^{-41d}$ where d = dose = exposure in mg EDB/kg/day

(5) The esimated spot contribution has been changed from the probable estimate (3.2 x 10^{-6}) to the realistic worst case (7.6 x 10 $^{-6}$) which is estimated in the J. Holder report dated 2/27/80. This realistic worst case has been adjusted by 3/4 in accordance with the most recent use information in Chapter IV, PD 4. The adjustment (0.75 x 7.6 x 10^{-6}) makes the dietary burden estimate for spot = 5.8 x 10^{-6} mg/kg/day.

2.) Dietary Burdens from EDB at Various Ages and Age-Related Variation in Risks to EDB due to one Year of Additional EDB Exposure

The estimated dietary burdens (DB) at ages of 2, 16, 30, and 50 years are presented in Table 12 with assumptions and example calculations presented in the footnotes. The total DB (and DB from each fumigation use) decreases with age (i.e., the DB is highest for the young*)

The estimates of dietary burdens in Table 12 are used to calculate estimates of cancer risks for one-year of additional exposure to EDB with observation for cancer for the rest of a normal (70 years) lifetime. It can be seen in Table 13 that these incremental risks decrease with age. Males were used for the calculation in Table 13. Female risks are approximately 20% less than the male risks.

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* These age-specific estimated dietary burdens reflect the variation with age of body weights and daily food consumption (both in total grams/day and in percentage of each type of food consumed per day). The later, variation of food factors with age, are not known at this time, but are being estimated by the Agency at this time and will be available at a later time (Chaisson, EPA).

Table 12: Dietary Burdens (DB) Resulting from EDB Fumigation Uses

(Age Specific Estimates)

(mg EDB/kg/day)

Fumigation Use	Estimated Dietary Burdens from EDB at the Age of (years): 2 years old	16 years old	30 years old	50 years old
Soil Incorporation (food only)	8.84×10^{-7}	3.91×10	3.15×10^{-7}	3.04×10^{-7}
Grain (wheat, bulk fumigation)	2.61×10^{-4}	1.21×10^{-4}	9.28×10^{-5}	8.97×10^{-5}
Spot (grain milling machinery)	8.38×10^{-6}	3.70×10^{-6}	2.98×10^{-6}	2.88×10^{-6}
Fruit Quarantine (in states not requiring fumigation)				
citrus-	1.40×10^{-6}	6.17×10^{-7}	4.97×10^{-7}	4.80×10^{-7}
tropical-	negligible	4.18×10^{-6}	3.50×10^{-6}	3.30×10^{-6}
Fruit Quarantine (in states requiring citrus fumigation)	1.44×10^{-5}	8.64×10^{-6}	6.96×10^{-6}	6.72×10^{-6}

Footnotes to Table 12 on the following page.

Footnotes for Table 12

1. Dietary Burdens (DB) are at the ages indicated and are calculated in PD 2/3 for 60 kg individual eating 1500 grams food day. DB's presented in PD 2/3 for 60 kg individual eating 1500 grams food/day. DB's presented in Table __ were converted to DB's here for different age groups by mulitplying by the appropriate correction factors for different food consumption and weight. For instance, for a two-year old male weighing 14.5 kg and eating 1232g/day:

soil fumigation DB (in PD 2/3)		conversion factors			Soil Fumigation DB (PD 4)
2.6×10^{-7} mg/kg/day	x	$\frac{60\ \text{kg}}{1500\ \text{g/day}}$	x	$\frac{1232\ \text{g/day}}{14.5\ \text{kg}}$	= 8.84×10^{-7} mg/kg/day
"average person" weighing 60 kg, eating 1500g./day					DB for 2 yr. old

This type of conversion was applied to soil incorporation, spot, and citrus quarantine fumigation uses where the contamination levels (in ppb of EDB) were reconsidered to be the same as in PD 2/3 and are carried over here (in Table 12) in the PD 4 for different age-group consumers.

Data used in the conversions:

	2 yr old	16 yr old	30 yr old	50 yr old
body weight (kgs.) -	14.5	60.94	73	77
daily food consumption - (grams/day)	1232	2288	2208	2250
conversion factors -	3.398	1.502	1.227	1.169

Female consumption and body weights accounted for a 20% (approx.) decrease in DB, and thus a 20% decrease in the female risks. The examples shown in Table 12 are based on male body weight and food consumption.

2. Bulk wheat grain fumigation was re-estimated to be higher than in the PD 2/3 estimate of 0.07 ppb and is now estimated to be 31 ppb EDB (see text for rationale).

The DB is calculated here is for a 16 yr. old male, assuming 100% of the commodity is contaminated at the 31 ppb level, and wheat products are 10.36% of the diet.

$$\text{DB} = \frac{31\text{x}10^{-9} \times 2288\ \text{g/day} \times 1000\ \text{mg/g} \times 0.1036}{60.94\ \text{kg body weight}} = 1.206 \times 10^{-4}\ \text{mg EDB/kg bw/day}$$

Footnotes for Table 12 (Cont'd)

3. The dietary burden for a "tropical food eater" is used for the quarantine use of EDB on tropical fruit to to be shipped to the continental U.S.
It was assumed that a reasonable level of consumption is 12 tropical fruits per year.
Thus, the DB can be calculated, for a 16 yr. old male in the U.S.:

$$\text{DB} = \frac{12\ \text{fruits/yr} \times 1\ \text{yr/365days} \times 0.25\ \text{kg /fruit} \times 0.031\ \text{mg EDB/kg fruit}}{60.94\ \text{kg body weight for a 16 yr old male}}$$

where 0.25 kg is the average weight of papayas and managers and mangos on per fruit basis 0.031 mg EDB/kg fruit = 31 ppb EDB average contmination level 12 fruits/yr. is assumed for the 16, 30, and 50 yr. old people and 2 year old children were assumed to eat negligible amounts of tropical fruit.

4. The total DB's from each use are summed from the Agency's current understanding of probable EDB contaminating sources. Sources of possible contamination include meat and milk. Meat and milk could be contaminated by livestock being fed on the farm, or in fattening feedlots, EDB contaminated grains. The Agency does not have data on these comodities, nor can any reasonable estimates be made at this time due to a lack of information.

Table 13: Incremental Risks from One Year of Additional

Dietary Exposure to EDB at Various Ages with Observation for Cancer for a Lifetime 1/

Fumigation Use	Beginning and Ending Age of One Year of Additional Exposure to EDB			
	2 to 3 yrs. old	16 to 17 yrs. old	30 to 31 yrs. old	50 to 51 yrs. old
Soil Fumigation - (food only)	2.0×10^{-6}	3.0×10^{-7}	3.5×10^{-8}	3.3×10^{-10}
Wheat Grain - (bulk)	5.8×10^{-4}	9.4×10^{-5}	1.0×10^{-5}	9.7×10^{-8}
Spot (Fumigation milling machinery)-	1.9×10^{-4}	2.9×10^{-6}	3.3×10^{-7}	3.1×10^{-9}
Fruit Quarantine (in states not requiring fumigation				
Citrus -	3.1×10^{-6}	4.8×10^{-7}	5.6×10^{-8}	5.2×10^{-10}
Tropical -	negligable	3.3×10^{-6}	3.9×10^{-7}	3.6×10^{-9}
Fruit Quarantine (in states requiring fumigation)				
citrus -	3.2×10^{-5}	6.7×10^{-6}	7.8×10^{-7}	7.3×10^{-9}

1.) The risk model used was that described in IV F. Risks for women were estimated to be approximately 20% less than males because of differences in dietary burden. Male risks are presented in this table.

H. Ground Water Cancer Risk

The model, discussed in Section III F, was used to estimate the cancer risks below.

The detection limits for EDB vary in different laboratories between 0.02 parts per billion (ppb) and 0.10 ppb. Therefore, the Agency has included these detection limits in Table 14 below, in addition to other observed contamination levels.

Table 14. Cancer Risks for EDB Ground Water Contamination

Concentration	Lifetime Cancer Risk*
0.02 ppb	3×10^{-5}
0.1 ppb	1.5×10^{-4}
1.0 ppb	1.5×10^{-3}
5.0	7.5×10^{-3}
100 ppb	1.5×10^{-1}

* EPA assumes consumption of 2 liters of water per day for an adult, a 60 kg lifetime average weight, and a 70 year lifetime. This 2 liter assumption includes water consumed per se, as well as water used in reconstituting powdered drinks, etc. Cancer risks, as presented in this table, are the additional risks estimated for a lifetime of exposure.

IV. Analysis of PD 2/3 Comments and Revisions Relating to Benefits

Detailed analyses of the benefits derived from registered uses of EDB are presented in the PD 2/3. Benefit analyses for the major soil nematicide sites have been substantially revised since issuance of the PD 2/3. The following discussion is a summary of the results of the updated analyses, as well as a summary of comments which were received in response to the PD 2/3 addressing the benefits derived from the use of EDB and the Agency's response to these comments.

1. Preplant Soil Fumigation

Ethylene dibromide is applied as a soil fumigant on numerous agricultural crops for nematode control. Use as a soil fumigant accounted for over 90 percent of the total pesticidal use of EDB in 1978. Since 1978 use of EDB as a soil fumigant has increased significantly. In 1978, the Agency estimated that cancellation of this use could result in adverse economic impacts of over $20.5 million annually (1978 nominal dollars). The 1983 analysis estimated that cancellation would result in adverse economic impacts at the user level from $26.4-$42.8 million (1983 nominal dollars) annually with additional effects at the market and consumer level.

When the original benefit analyses, used as input to the EDB PD 2/3 were made, the soil nematicide market was unstable due to regulatory action anticipated on dibromochloropropane (DBCP). The PD 2/3 benefits analyses incorporated assumptions which were subject to uncertainty concerning how EDB would be used in the absence of DBCP. In addition, since issuance of the PD 2/3, EDB was registered for use as a soil nematicide on soybeans. This registration now accounts for approximately half of total EDB pesticidal use.

Due to new concerns over EDB contamination of groundwater and substantive changes in EDB's soil nematicide market since the PD 2/3, new benefit analyses on the major soil nematicide sites were conducted during the summer of 1983. The analyses were undertaken to identify the locations and volumes of the current use of EDB as a soil nematicide, and to assess the current (1983) benefits of this use. New benefit analyses were completed for soybeans, California vegetables, cotton, peanuts, tobacco, sweet potatoes, white potatoes, and pineapples. The results of these analyses are summarized in Table 15.

Currently, approximately 1.0 million acres are treated for nematode control with nearly 23 million pounds of EDB active ingredient annually. The major use sites are soybeans (12.8 million pounds active ingredient), cotton (4.5 million pounds active ingredient), and peanuts (2.2 million pounds active ingredient) with lesser volumes applied to other crops. Most of the use is located in the southeastern United States.

Soybean, peanut, and pineapple growers are expected to experience the largest economic impacts. Aggregate annual impacts at the user level range from $26.4-$42.8 million annually dependent in the selection and efficacy of available alternatives. The primary substitutes for EDB soil nematicide formulations are expected to be D-D, Telone®, Nemacur®, Mocap®, Furadan®, and Temik®.

Table 15. Annual Economic Impacts of the Cancellation of EDB As a Soil Nematicide on Major Use Sites

Crops	Acres Treated	Active Ingredient	Economic Impacts	
			User	Market Consumer
	000's acres	000's pounds		
Soybeans	532.8	12,787.0	User impacts of $7.0 million due change in control costs. Price of soybean oil may increase by $0.01-$0.03 per pound. No loss in production is anticipated.	Welfare losses to consumers of about $7 million in second year after cancellation, with decreasing losses in later years (declining to $0 in 5-7 years).
California Vegetables [1]			User impacts resulting from increased nematode control costs. No loss in production anticipated.	Increased production costs may cause some users to grow different crops. Consumer impacts would be negligible.
Tomatoes	8.7	177.3	Increased control costs of alternatives range from $0.3-$1.1 million	
Beans[2]	11.4	173.6	Increased control costs of alternatives range from $0.5-$1.5 million	
Carrots	3.7	68.2	Increased control costs of alternatives range from $0.5-$1.5 million	
Other produce (melon, watermelon, squash, bell peppers, asparagus, head lettuce, cucumber peas, cauliflower pumpkin, parsnip)	2.3	70.5	Increased control costs of alternatives range from $0.1-$0.3 million	

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[1] EDB use was recently suspended by CDFA in the countries of Fresno, Kern, Merced and Stanislaus. These counties apply a significant proportion of the EDB used in California. The decrease is not reflected in the estimates given in this table.

[2] Represents use on both green lima beans and dry lima beans.

Table 15. Annual Economic Impacts of the Cancellation of EDB As a Soil Nematicide on Major Use Sites (Cont'd)

Crops	Acres Treated	Active Ingredient	Economic Impacts	
			User	Market/Consumer
	000's acres	000's pound		
Cotton	185.0	4,500.0	$3.0 million user impacts. Primarily southeast region. Impacts result from increased production costs. No loss in production is anticipated.	An additional cost for nematode control could cause growers to change crops. This would most likely occur in the southeast region. Negligible consumer impacts.
Peanuts	134.5	2,151.8	Change in control costs of $4.1 million. Change in value of production of $3.8 million due to planting delay and reduced efficacy.	None.
Tobacco (flue-cured)	68.1	913.6	Aggregate increase in treatment cost $2.02 million. No loss in production anticipated.	None.
Sweet Potatoes	9.1	160.2-236.4	$0.3-$0.5 million user impacts resulting from increased control costs. No loss in production anticipated.	None.
White Potatoes	22.5	960.0-1080.0	User impacts from increased control costs $1.6-$2.2 million. No loss in production anticipated.	Negligible.

Table 15. Annual Economic Impacts of the Cancellation of EDB As a Soil Nematicide on Major Use Sites (Cont'd)

Crops	Acres Treated	Active Ingredient	Economic Impacts	
			User	Market/Consumer
	000's acres	000's pound		
Pineapples	4.0	810.0	Assuming newly registered alternative is efficacious, user impacts will range from \$3.6-\$5.0 million annually in increased nematode control costs and losses in value of production. In addition, up front capital investiments of \$3.2-\$6.9 million will be necessitated. If newly registered alternative is not efficacious, user impacts of \$15.8 million annually in increased nematode control costs and losses in value of production are anticipated. In either case, since pineapple companies are vertically integrated, additional losses in profit may be incurred at processing and marketing levels due to reduced production and increased average costs per unit.	Due to the oligopolistic nature of pineapple industry, any market/consumer impacts cannot be quantified; however, substantial losses in production could result in prices increases at the consumer level, if alternative are not adequately effective.
Total	982.1	22,772,2-22,968.4	\$26.4-\$42.8 million in increased nematode control costs and losses in value of production. At \$26.4 million, capital investments of \$6.9 million would be incurred by pineapple growers.	

Sources: See Additions to Bibliography (Economics)

The cancellation of EDB for use on soybeans would result in increased nematode control costs of $7.0 million annually for soybean growers. The 1981 value of U.S. soybean production was approximately $13 billion. Cancellation of EDB for use on peanuts would result in increases in control costs of $4.1 million and reduced value of production estimated at $3.8 million annually. 1981 value of U.S. peanut production was approximately $1.0 billion.

Data submitted to the Agency indicates that the magnitude of the economic impacts are most likely dependent on the efficacy of Nemacur®, a newly registered systemic nematicide. If Nemacur® performs adequately, pineapple growers would experience annual losses due to increased nematode control costs and losses in value of production of $3.6-$5.0 million annually while incurring capital costs of $3.2-$6.9 million. If Nemacur® is not efficacious, economic impacts could increase to $15.8 million annually in losses in value of production and increased nematode control costs. These impacts are large relative to the value of pineapple production; 1981 value of Hawaiian pineapple production was estimated at approximately $90 million.

Telone II®, a preplant chisel injected nematicide, can be applied to Hawaii pineapple for control of the root-knot nematode, Meloidogyne javanica (Treub). EDB is applied for control of the reniform nematodes, Rotylenchulus reniformis (Linford). If Telone II®, without Nemacur®, provided nematode control equivalent to EDB, growers would experience increased nematode control costs of approximately $0.5 million annually.

However, EPA has not received documentation that Telone II® alone can achieve comparable efficacy to EDB.

2. Stored Grain Fumigation

The conclusions reached following the benefits analysis of EDB fumigation of stored grain in the PD 2/3 concluded that alternatives were available. EDB for this use would probably be replaced by the carbon tetrachloride/carbon disulfide (CT/CD) and/or aluminum phosphide. Other potential alternatives were identified but are not anticipated to capture a significant portion of the liquid grain fumigant market in the near future. Carbon dioxide has since been registered for this use.

Hopes Consulting, Inc. (Hopes) submitted a detailed evaluation (Comment #26) of the benefits derived from the use of EDB to control insect pests of stored grain. Additional information was also provided by the Douglas Chemical Co. (Douglas) and by the U.S. Department of Agriculture (USDA). The comments and additional information are discussed topically.

a. Revised Estimate of Rate and Frequency of Application

Using methodology similar to that used in the Agency's Preliminary Benefit Analysis, Hopes estimated the economic impact of cancelling EDB. Hopes estimated an increase in user costs of more than $56 million as compared to the Agency's estimate of a possible slight decrease in user costs. Differences in rates and frequencies of application assumed in the PD 2/3 and by Hopes account for the large variance in estimated user impact. The Agency's calculations were based on rates and frequencies of application from product label data and State and Federal pesticide use recommendations for EDB and CT/CD. Hopes used an application rate for CT/CD which is double that of EDB and also estimated that CT/CD would be used twice as often as EDB (e.g., four times annually versus twice annually for EDB). Douglas, a major producer and distributor, indicated that currently, only one annual EDB treatment occurs at a typical rate of about 2 gal/1000 bushels of grain. These data more closely approximate the Agency's original estimates and indicate that usage rates for EDB may have declined slightly. The Agency believes that the Douglas data approximate current label information and are more indicative of current use than are the Hopes data.

b. Additional Estimates of Volume for Grain Fumigation

Hopes estimated approximately 4.56 million gallons of EDB formulations were used to treat stored grain. The Agency estimated approximately 1 million gallons were used. The USDA provided preliminary results of a study titled "An Interim Analysis of EDB Use in On-Farm Storage." This analysis indicates 57,492 pounds of EDB were used on farms. Douglas estimated on-farm use of the active ingredient EDB, to be 202,000 pounds in 1981 and that liquid grain fumigants containing EDB approximates 375,000 to 425,000 gallons annually.

c. Conclusions On Stored Grain Fumigation Use

Based on available use recommendations and label data, the Agency believes that Hopes has overestimated the rate and frequency of applications of both EDB and CT/CD. As a result of overestimated usage, Hopes has also overestimated the benefits attributed to EDB usage.

The Agency believes current usage of EDB and CT/CD is probably less than typical usage levels in the mid to late 1970's when the PD 2/3 benefit analysis was conducted.

3. Spot Fumigation of Grain Milling Machinery

EDB has been used for more than 20 years as a spot fumigant to control insect pests that infest flour milling equipment. The only alternative spot fumigant is a mixture of 75 percent ethylene dichloride and 25 percent carbon tetrachloride; however, the dosage required for this pesticide is so large that the milling industry does not consider it to be a viable broad scale alternative. The overall results of using this substitute include the application of a much greater quantity of pesticide, a higher cost for fumigation, greater labor costs, and more down time for the mill.

The Agency also determined that the most likely alternative to EDB for spot fumigation is general fumigation of the entire mill spaces. Methyl bromide (MB) and aluminum phosphide (AlP) are currently the two most commonly used general space fumigants. The Agency projected in the PD 2/3 that at least 3-5 additional general fumigations per year would be required to obtain control. Based on a comparison of current practices versus the use of alternatives, the PD 2/3 indicated an increase in costs of $2.9 to $6.0 million annually for use of 3 and 5 additional general space fumigations respectively. The Agency has received numerous comments regarding the viability, efficacy, and costs of alternatives to EDB for controlling insects which infest flour milling machinery. Commenters provided substantive data for four broad issues: a) EDB alternatives and their efficacy, b) EDB usage estimates, c) frequency of application, and d) EDB spot treatment costs versus the costs of general fumigation. The comments are discussed below and analyzed.in detail in a separate document titled "Analysis of Comments on Proposed Action on EDB Use in Spot Fumigation of Milling Equipment" (Holtorf and Ludvik, 1982).

a. Efficacy of Alternatives

The Agency's assessment of the efficacy of methyl bromide (MB) or aluminum phosphide (AlP) as alternatives to EDB was questioned by Ferguson Fumigants Inc. (Comment #22) and by USDA. Ferguson argued that neither MB nor AlP are pupacidal and that only EDB alone is efficacious in controlling tolerant life stages such as the egg and especially the pupal stage. However, the Agency is aware of a number of studies which present data that demonstrate the pupacidal activity of MB or

AlP. These studies include: Kazmaier and Fuller (1959), Krohne and Lindgren (1958), Lindgren et al., (1958), and Munro (1969). The Kazmaier and Fuller study also indicates MB and AlP are ovacidal (effective against egg stage). Therefore, the Agency rejects the contention that EDB is the only efficacious compound for controlling all life stages.

b. Usage Estimates

Ferguson Fumigants Inc., the Miller's National Federation, and the USDA all submitted data which indicate that the overall quantity of EDB usage in spot fumigation may be less than that estimated by the Agency in the PD 2/3. The analysis of benefits presented in PD 2/3 was based on the assumption that all mills used EDB spot treatments. Although the usage estimates provided by the commenters were not consistent, the new data indicate that approximately 75 percent of the wheat flour milled in the U.S. is produced in mills treated with EDB.

Because the Agency's original assessment was incorrect, the overall benefits of EDB use in flour milling are less than were estimated in the PD 2/3. Consequently, because fewer mills than previously estimated use EDB, the relative costs of substituting general space fumigation for spot treatments were also overestimated in the PD 2/3.

c. Frequency of Application

The single, most often discussed issue is that of the frequency of general fumigations necessary to maintain insect control.

Most comments indicated that 4 or 5 general fumigations would not be adequate to maintain effective control. Commenters stated that general fumigation would have to be practiced on the same schedule as spot fumigation or about 12 to 14 fumigations annually. One commenter (Comment #44) indicated that general fumigation may be practiced 8-10 times annually. It was indicated in the preliminary benefit analysis, however, that frequent (i.e. 12-14 per year) general fumigations would be prohibitively expensive, and that the industry would probably adopt a strategy which would utilize fewer general fumigations.

The Agency received comments that even 4 or 5 general fumigations would be prohibitively expensive (Comment #43), and that general fumigation would not be conducted even 4 or 5 times per year to replace spot fumigation (Comment #1A). Though arguing that 4 or 5 general space fumigations would not substitute for spot fumigations, the commenters did not provide the Agency with data to support their claim that general fumigation is ineffective.

The Miller's National Federation (MNF) surveyed 27 member firms which produce approximately 80% of the wheat flour milled in the United States (Henwood, 1982). Their survey, in addition to a previous MNF survey on total usage of EDB, provides the most definitive source of information available regarding the frequency of application of EDB in the milling industry. The Henwood study indicates that, of the mills surveyed, those treated with EDB produce about 75% of the daily capacity of the industry and that each mill is treated with EDB an average of about 10 times per year.

In summary, the comments submitted to the Agency indicating that current usage of EDB for spot fumigation is less than estimated in PD 2/3; that EDB is used less frequently than indicated in PD 2/3; and that the amount of flour exposed to treatment is less than indicated in the PD 2/3. The Agency recognizes that general fumigations will require more diligence in regard to sealing mills and maintaining duration of exposure to obtain control of insect pests in flour mills. The Agency does not believe that the milling industry will be required to make 12-14 general space fumigations annually rather than 4-6 general fumigations as indicated in the preliminary analysis. The Agency has concluded that the information submitted by commenters does not adequately support their contention that alternatives to EDB would not be used, or the Agency's preliminary benefits analysis failed to consider appropriate facts.

d. Treatment Costs

Three respondents provided mill-specific information on comparative costs of spot vs. general fumigation in their mills. The Ohio Department of Agriculture (Comment #14) noted that the cost of a complete general mill fumigation is about $5,400 compared to a spot fumigation cost of $600. These costs did not include the charge for "down time".

The Hawaiian Flour Mills, Inc., (HFM) (Comment #29) provided a detailed breakdown of the costs of general and spot fumigation. HFM indicated that their fumigation costs would increase from $8,774 annually using EDB to $24,079 annually for general fumigations using aluminum phosphide and in addiiton they would lose of 4 to 5 production days per year. HFM did not provide data regarding the frequency that EDB was currently being used in their mills nor were data submitted on how frequently general fumigation or other controls would be used if EDB were cancelled. North Dakota Mills and Elevator (Comment #27) indicated that each general fumigation costs approximately $4,800 while each spot fumigation costs approximately $500.

The National Pest Control Association Inc. (NPCA) (Comment #44) submitted estimates of the impact of cancelling EDB in wheat, rye, and corn mills. NPCA estimated that use of general mill fumigation in the wheat and rye milling industry would increase treatment costs by about $12.8 million annually ($43,000 per mill) if 8 general fumigations replaced EDB spot fumigations. For corn mills, NPCA estimated an increase of $2.6 million annually ($28,000 per mill) again, basing their estimates on 8 annual general fumigations. Ferguson Fumigants, Inc. (Comment #33) provided a 1978 analysis of the cost of replacing EDB with general space fumigation. They estimated that the cost to the milling industry of using methyl bromide would be approximately $24.1 million annually as compared with about $1 million for an EDB program. This analysis assumed that general fumigation would replace spot treatment on a one-to-one basis; therefore, 13.7 general fumigations per year would be required throughout the entire milling industry.

The NPCA 1981 estimate of $15.4 million (using 8 general fumigations) is about double the Agency's preliminary 1978 estimate of approximately 7.8 million (using 5 general space fumigations including the one normally scheduled). The Ferguson Fumigants Inc. estimate of $24.0 million assumed 13.7 general fumigations. The NPCA and Ferguson Fumigants estimates appear to be based on the cost of using general fumigation throughout the entire milling industry. However, EDB usage is apparently not as widespread as previously believed and could be 25% to 50% less than was estimated in the PD 2/3 (i.e., 50% to 75% of the mills use EDB). These estimates of the cost of space fumigation are therefore overestimated to the extent that they rely on the assumption that cancellation of EDB would impact the entire milling industry.

Although data are not available to estimate with precision the frequency of usage of general fumigation in place of spot treatments, The NPCA 1981 estimate (based on 8 general fumigations) of $15.4 million, certainly is not unreasonable and shows relatively close agreement with the PD 2/3 estimate. Allowing for inflation of input factors during the 1977 to 1981 period. The estimated impacts presented in the PD 2/3 would be higher and could be expected to converge with the NPCA estimates, especially if the PD 2/3 estimates were recomputed based on 8 general fumigations. The Agency does not believe that the milling industry, on average, will adopt a schedule of 13.7 general fumigations as suggested by Ferguson Fumigants Inc. The high cost and added inconvenience of general fumigation will force millers to limit the number of general fumigations to a schedule which is less frequent than is currently practiced with the spot materials.

e. Conclusions on Spot Fumigation

Comments submitted in response to the PD 2/3 generally agreed with the Agency's preliminary assessment of benefits that cancellation of EDB use in spot fumigation will increase the cost of insect control in the milling industry. The comments stressed that in comparison to whole mill fumigation (with MB or AlP), EDB spot treatment is much more convenient, more effective in certain situations and is much less expensive. The comments did not provide new data, information, or arguments which could persuade the Agency to alter its preliminary findings.

4. Quarantine Fumigation of Citrus, Tropical Fruits, and Miscellaneous Fruits and Vegetables

The U.S. Animal and Plant Health Inspection Service (APHIS) and the states of Texas, Hawaii, Louisiana, California and Arizona require the use of EDB in their fruit fly quarantine programs. Prior to March, 1982, the Japanese government also required EDB fumigation as the only approved method of treating all fresh citrus and tropical fruit imported from the U.S. In PD 2/3, the Agency estimated that major economic impacts would occur if EDB were cancelled for these uses. Depending on the acceptability of cold storage and/or irradiation as viable technological alternatives, the magnitude of adverse economic impacts may be reduced. Several comments pertaining to the estimates of benefits were submitted. Most of the comments claimed an increased need for EDB due to recent infestations of the Mediterranean and Oriental fruit flies in California. A second major concern is the viability of gamma irradiation as an alternative to EDB post-harvest fumigation.

Several commenters (Comments #3, #10A, #20) argued that the 1981 Mediterranean fruit fly infestations in California have increased the need for, and thus the benefits derived from the use of EDB fumigation. Due to the uncertainty associated with predicting the extent and/or intensity of future medfly infestations, the Agency has not modified the original estimates of benefits. In March, 1982, the Agency was informed that the Japanese government has approved the use of cold storage, for those commodities adaptable to the procedure (oranges and grapefruit) infested with the Mediterranean fruit fly.

The USDA/APHIS is currently in the process of developing cold storage procedures for treatment of the Carribean fruit fly (Helms, Personal Communications, 1982a and b). As of August 1983 experimental data indicated that Carribean fruit fly eradication is technologically feasible using cold storage for shipments to Japan (Vlier, personal communication). Although results indicate technological feasiblity, it is uncertain whether Japan will accept the cold storage quarantine method for the Carribean fruit fly.

With regard to interstate citrus shipments and quarantine regulations, some progress has been made in reducing the need of EDB treatments to Texas citrus. Over the past 2 harvest seasons (1981/1982, 1982/1983) APHIS has implemented a Mexican fruit fly certification program in Texas. The program measures fruit fly populations and determines whether those populations are low enough to allow interstate shipment of citrus without quarantine treatment. Theoretically, the certification program will reduce the need for quarantine treatment; however, since fly population levels can increase, not all fruit in all Texas locations and harvest periods can be certified as pest free. Therefore, alternative controls for EDB fumigation must be available as back-up to the certification program to avoid adverse economic impacts.

The U.S. Department of Agriculture (USDA), the Hawaii Papaya Industry Association (HPIA), the Hawaii State Department of Agriculture (HA), and the California Citrus Quality Council (CCQ) all indicated that they do not consider gamma irradiation to be a feasible alternative by July of 1983. However, the Food and Drug Administration has published an Advance Notice of Proposed Rulemaking 46 FR, 18992-3) which initiates the process to establish criteria for evaluating petitions for irradiated foods. In addition, FDA has authorized the use of irradiation in emergency situations to control Mediterranean fruit fly in infested fruit (Hayes, 1981). The Agency has now extended the phase out of the EDB quarantine use until September 1, 1984, to provide additional time to implement alternatives.

The Hawaii Papaya Industry Association (Comment #23) indicated that approximately 91 percent of the Hawaiian papayas were marketed as fresh fruit with approximately 74 percent being shipped to the mainland U.S. and to Japan. The HPIA contends that a cancellation of EDB, without suitable alternatives, would totally destroy the Hawaiian papaya industry. The Agency acknowledges that a lack of acceptable control measures would have serious negative impacts on the papaya industry. However, if FDA approves the use of irradiation for papaya and if irradiation is acceptable to Japan, the economic impacts on the Hawaiian papaya industry are expected to be less substantial.

The Hawaii State Department of Agriculture indicated that currently, papayas are grown and fumigated on at least three different islands and that construction of irradiation facilities at each location would be economically unsound. The Department also indicated that a central irradiation facility would increase shipping costs and drastically increase the amount of handling. Although the Agency agrees that such circumstances could result in economic impacts, the State of Hawaii did not submit data which would allow the Agency to quantify these concerns. The Agency has further determined that papayas are fumigated on only two islands, Hawaii and Kauai, and that most of the fumigation occurs on Hawaii.

The Agency is aware that several commercial enterprises are in the process of designing and building gamma irradiation facilities in several locations in California and Florida. In light of the pending FDA rulemaking and the proposed construction of gamma irradiation facilities, the Agency believes that gamma irradiation should be considered as a potential alternative to EDB fumigation in the future.

The USDA asserted that a cancellation of EDB would weaken the trade positions with Mexico, Haiti, Israel, and Morocco. USDA contends that suitable alternatives to EDB are not available for citrus and tropical fruits originating in these countries. However, the USDA did not provide data demonstrating that cancellation of EDB would adversely affect those trade positions with Mexico, Haiti, Israel, or Morocco. EPA, however, concludes that these exporting nations will have available the same alternatives for EDB use as United States growers.

5. Felled Log Fumigation

In PD 2/3, the Agency estimated 68,000 logs annually in Colorado and North Dakota were fumigated with EDB to control several species of bark beetles. When the PD 2/3 Benefits Analysis was performed, endosulfan and lindane were registered alternatives, but the Agency did not consider lindane as a viable alternative due to its status as an RPAR chemical. Although endosulfan was considered less effective than EDB or lindane, the Agency concluded its use for bark beetle control could reduce treatment costs as much as $36,000 annually (1978 nominal dollars). The Forest Service, Larimer County, Colorado, provided data on the benefits of using EDB on felled logs. The process, from felling through treatment, costs $10 to $100 per tree and cannot be conducted on a scale large enough to effectively reduce bark beetle populations. In addition, the Forest Service indicated that control costs in conjunction with adverse health effects have resulted in a decision to suspend further use of EDB in bark beetle control projects in Larimer County.

The U.S. Department of Agriculture responded to the PD 2/3 by noting that endosulfan is not specifically registered to control the mountain pine beetle and that the Department was not aware of efficacy data comparing endosulfan with EDB. The USDA further stated that lindane is actually the compound of choice, as an alternative to EDB for treatment of the mountain pine beetle.

The Agency did not receive sufficient additional information that would allow an improved estimate of the benefits derived from the application of EDB to felled logs. The Agency, however, is reevaluating its preliminary decision to cancel the use of lindane on felled logs, and is likely that this preliminary decision will be reversed. Thus, lindane will probably be available as an alternative to EDB. In sum, the economic impacts of an EDB cancellation would be minimal for this use.

6. Minor Uses

The Agency did not receive substantive data for other uses of EDB. Therefore, the Agency has no basis to change the original assessments as contained in PD 2/3. Consequently, the PD 2/3 estimates of benefits resulting from the following uses of EDB are not revised: termite control, fumigation of stored beehive supers and honeycombs, fumigation of stored clothing, furniture, and quarantined plants, soil and grass sod.

V. Summary and Conclusions

The Agency has determined that EDB is a potent animal carcinogen, a mutagen to a variety of plant and animal cells, and is capable of producing adverse reproductive effects in animals. EDB is potentially capable of producing these adverse health effects in humans at measurable levels in the human diet, in the ambient air of application sites, and in the ambient air of facilities where treated commodities are handled and stored. The Agency has carefully weighed the human health risks against the economic benefits for each use of EDB. The Agency has determined that no remedial changes can be made in the registration of EDB for most uses to avoid unreasonable adverse effects on human health.

The Agency further has determined that continued registration of EDB as a soil fumigant poses an imminent hazard during the period in which administrative hearings would delay the the cancellation of these registrations. Continued use of the chemical during these hearings would contribute additionally to an already serious hazard. Emergency suspension is the only mechanism available to the Agency to cease immediately the use of a pesticide. The Agency has also determined that an emergency exists resulting from the soil fumigant use of EDB such that an emergency order should be issued immediately suspending these registrations.

The Agency has further determined that the registrations for use as a soil fumigant, grain fumigant, spot fumigant and felled log fumigant should all be cancelled. The Agency, however, has determined that the cancellation of EDB products used for fumigating citrus, tropical fruit and vegetables should not be made effective until September 1, 1984, in order to allow time for alternatives for this use to become available on a commercial scale. The Agency has decided to continue registration of EDB products used for the minor uses of termite control, fumigation of beehive supers and honeycombs, vault fumigation and Japanese beetle control, only if specified changes are made on the labels to reduce the risks presented by these uses.

A summary of the Agency's final regulatory decision on EDB is presented in Table 16, and the details of the regulatory decision are presented in the Federal Register Notice announcing the availability of this document.

TABLE 16--SUMMARY OF FINAL REGULATORY DECISION ON EDB

Soil Fumigation	Cancellation effective 30 days after this Notice; Emergency Suspension effective immediately.
Stored Grain Fumigation	Cancellation effective 30 days after this Notice.
Quarantine Fumigation of Citrus, Tropical Fruits and Vegetables	Cancellation effective September 1, 1984.
Spot Fumigation of Grain Milling Machinery	Cancellation effective 30 days after this Notice.

Felled Log Fumigation	Cancellation effective 30 days after this Notice.
Termite Control, Beehive Supers, Vault Fumigation, Japanese Beetle Control	Continued registration with label changes imposing use restrictions; require submission of monitoring and use data.

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APPENDIX I

ETHYLENE DIBROMIDE: POSITION DOCUMENT 2/3

OFFICE OF PESTICIDE PROGRAMS
U.S. ENVIRONMENTAL PROTECTION AGENCY
DECEMBER, 1980

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EXECUTIVE SUMMARY

This Position Document (PD) 2/3 proposes several regulatory actions to reduce the human health risks resulting from registered pesticidal uses of ethylene dibromide (EDB). These proposed actions are based on the Agency's determination that certain uses of EDB result in unreasonable adverse effects to man. The Agency requests registrants and interested parties to review the proposed actions and the evaluations upon which they are based, and to provide comments or any additional relevant information. All of the registered uses of EDB have been examined in this document. These include: preplant fumigation of soil (to control nematodes); fumigation of stored grains (to control insects); spot fumigation of grain milling machinery (to control insects); post-harvest fumigation of citrus, tropical fruits, and vegetables under USDA Animal, Plant and Health Inspection Service (APHIS) quarantine (to control fruit flies); fumigation of felled logs (to control bark beetles); fumigation of stored beehive supers and honeycombs (to control the greater wax moth); vault-fumigation of stored furniture and clothing (to control various pests); treatment of plants, soil and grass sod in accordance with the USDA/APHIS Japanese Beetle Quarantine Program; and fumigation beneath concrete slab foundations of buildings and porches to control subterranean termites, and spot fumigation of their galleries to control drywood termites.

The first regulatory action the Agency is proposing is to allow registration to continue for preplant soil fumigation, the largest volume use of EDB. However, the Agency will permit this use only if certain restrictions are implemented and additional data requirements are fulfilled. Specifically, the Agency will require applicators to wear respirators and protective clothing; reentry into a treated field will also be prohibited for 24 hours following fumigation. The Agency is also requiring soil fumigant registrants to conduct studies to determine if this use results in groundwater contamination. The need for these studies is based on the concern that EDB is structurally similar to dibromochloropropane (DBCP), a chemical also used as a preplant soil fumigant, which has been found in many groundwater supplies. In addition, the Agency will require registrants to provide data to demonstrate that residues of EDB in crops grown in EDB fumigated soils at maximum allowed application rates do not exceed the limits of sensitivity of analytical methodology (currently 1 ppb). When results from these investigations are available, the Agency will reexamine the adequacy of its regulatory measures for this use.

Second, the Agency is proposing to cancel the EDB registrations for two other major uses: fumigation of stored grains and spot fumigation of grain milling machinery. The bases for these proposed cancellations are that the public health risks of cancer, heritable genetic damage, and reproductive disorders outweigh the economic benefits of these uses. The Agency has concluded that residues of EDB contaminate the human diet as a result of these registered uses. Applicators, persons near a treatment site and workers who handle treated commodities are also exposed to significant levels of EDB via inhalation and dermal contact.

Third, the Agency is proposing that on July 1, 1983, EDB registrations for post-harvest fumigation of citrus, tropical fruits and vegetables will be cancelled. The interim period of allowed use will give time for the development and implementation of efficacious alternatives. There are currently no effective means of protecting these commodities from fruit fly

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infestations other than EDB. However, gamma irradiation treatment methods are currently being considered. These have been used successfully in several foreign countries.

Fourth, the Agency is proposing to cancel the EDB registration for fumigation of felled logs, a relatively low volume use. The basis for this action is the Agency's determination that the potential risks to applicators outweigh the economic benefits of this use. Based on the current application methods for this use, the Agency has concluded that applicators may be at risk of incurring unreasonable adverse effects resulting from dermal contact and inhalation of EDB vapors. Because the use of the registered alternative endosulfan would result in a national reduction in treatment costs, the Agency has established that there are no benefits for this use of EDB.

Fifth, the Agency is proposing to defer the decision on the use of EDB for control of termites, but in the interim will reinforce and expand current label directions by requiring that it be used only by certified commercial applicators; that applicators must wear protective clothing and a respirator; that premises be vacated by non-applicators during fumigation and subsequent aeration; and for use against subterranean termites, that injection holes be plugged temporarily during, and sealed permanently after, treatment. The Agency defers further regulatory action on uses against termites until EDB can be considered in a "cluster analysis" together with all other pesticides used for control of subterranean and drywood termites (including aldrin, dieldrin, chlordane, heptachlor, pentachlorophenol, chlorpyrifos, methyl bromide, sulfuryl fluoride, hydrogen cyanide, and silica aerogel).

Finally, for the remaining uses: fumigation of beehive supers, vault fumigation of stored clothing and furniture, and the USDA's Japanese Beetle Quarantine Program, the Agency is proposing to allow these uses to continue only if certain use restrictions are implemented and additional data requirements are fulfilled. Specifically, the Agency will require protective clothing and other low-cost measures designed to reduce applicator exposures to EDB. In addition, the Agency will require registrants of products with each of these uses to conduct studies to determine the EDB air levels to which applicators are exposed, the number of applicators involved in these uses, and the amounts of EDB applied annually for these uses.

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I. Introduction

A. General Background and Organization

The Federal Insecticide, Fungicide and Rodenticide Act, as amended (FIFRA), requires the Environmental Protection Agency (EPA) to review the risks and benefits of the uses of pesticides suspected of causing adverse effects to human health or the environment. On December 14, 1977, EPA issued a Notice of Rebuttable Presumption Against Registration and Continued Registration (RPAR) of pesticide products containing ethylene dibromide (EDB), a fumigant insecticide and nematocide. The rebuttable presumption was based on validated studies showing that EDB is oncogenic and mutagenic, and has adverse reproductive effects on several species of animals. Since then EPA has reviewed rebuttal comments and conducted thorough risk and benefit analyses of the pesticidal uses of EDB.

This document determines what regulatory actions EPA should take under FIFRA to change the current use patterns of pesticides containing EDB. Included are discussions about the risks and benefits of the pesticidal uses of EDB, and explanations about the rationale for the Agency's proposed final decision. This document is written in five chapters. Chapter I is this introductory section. Chapter II summarizes and evaluates the comments received on the RPAR, evaluates the potential health risks of EDB, and briefly describes the laboratory evidence of toxicity, available exposure data, available epidemiology data and the Agency's revised risk assessment. Chapter III summarizes the use-by-use economic benefits of EDB and the assumptions and limits of these estimates. Chapter IV describes possible regulatory options for the reduction of risks. Chapter V evaluates the risks and benefits and adverse impacts of each possible action for each of the nine general categories of the registered uses of EDB, and selects the regulatory action the Agency is proposing for each use.

B. Legal Background

1. The Statute

The FIFRA (7 U.S.C. Section 136 et seq.) regulates all pesticide products. Under Section 12(a)(1)(A) of FIFRA all pesticide products must be registered before they may be sold or distributed. Before a pesticide may be registered, the Administrator must determine that its use will not result in "unreasonable adverse effects on the environment," which is defined by Section 2(bb) of FIFRA to mean "any unreasonable risk to man or the environment, taking into account the economic, social, and environmental costs and benefits of the use of any pesticide." In sum, any decision to register or continue to register a pesticide must weigh both the risks and the benefits from the use of the pesticide.

Section 6(b) of FIFRA authorizes the Administrator to issue a notice of intent to cancel the registration of a pesticide or to change its classification if it appears to him/her that the pesticide or its labeling "does not comply with the provisions of [FIFRA] or, when used in accordance with widespread and commonly recognized practice, generally causes unreasonable adverse effects on the environment."

Table 1. Physical Properties of EDB 1/

Boiling Point	131.5°C
Melting Point	9.3°C
Vapor Pressure	11.0 mm Hg @ 25°C
Specific Gravity	liquid (water @ 4°C =1) 2.172 @ 20°C gas (air =1) 6.487
Solubility	0.43 g/100 g water @ 30°C, soluble in ethanol, ether and most organic solvents.
Stability	Stable
Flammability	Nonflammable
Appearance	Colorless liquid
Heat of Vaporization	46.2 cal/g
Corrosiveness	vapor or liquid attacks many paints and some metals (especially aluminum)
Flash Point	None
Fire Point	None
Weight & Volume Conversions	1 U.S. gallon = 18.11 lbs.
	1 U.S. gallon = 8.215 kg.
	1 lb. liquid = 208 ml @ 25°C
	1 oz/1000 ft^3 = 1 mg/liter = 1 gm/m^3
	1 ppm = 7.69 mg/m^3
	1 mg/m^3 = 130 ppb
Density of EDB in saturated air	1.08 (air = 1)
Conc. of EDB in air at saturation	1.3% by vol. @ 20°C

1/ Data taken from several sources including Monro (1969), Thomson (1977), Martin (1971), Spencer (1973), Merck (1976).

The Administrator may also cancel the registration of a pesticide if its labeling does not comply with the misbranding provisions of FIFRA which require the labeling to contain language "adequate to protect health and the environment" [FIFRA Section 2(q)].

2. The RPAR Process

The purpose of Rebuttable Presumption Against Registration (RPAR) is to gather risk and benefit information about pesticides which appear to pose risks to health or to the environment. As described in 40 CFR 162.11, this process is designed to allow an open, balanced decision with participation by all interested groups. The RPAR regulations describe various risk criteria, and provide that an RPAR shall arise if the Agency determines that any of the risk criteria have been met. Once a notice of rebuttable presumption is published, registrants, applicants and interested persons may submit evidence in rebuttal or in support of the presumption. All parties may also submit evidence on the economic, social and environmental benefits evidence of any use of the pesticide. If the presumptions of risk are not rebutted, the evidence of the benefits from use of the pesticide submitted to or gathered by the Agency must be evaluated and considered with the risk information. The Agency analyzes various risk reduction methods and their costs. The Agency then determines whether or not the risks of pesticide use may be outweighed by its benefits. If a balance between risks and benefits cannot be reached for a specific use, the registration for that use must be canceled or otherwise restricted, or, in the case of a new application, denied.

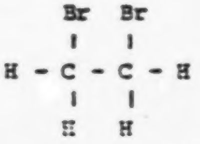
C. Chemical Background

1. Nomenclature

Ethylene dibromide (EDB) is the common name for 1,2-dibromoethane, CAS number 0001060934. It is a soil and commodity fumigant having both nematocidal and insecticidal use. The term EDB as used in this document refers specifically to the organic molecule, ethylene dibromide, and does not include its breakdown products, such as inorganic bromide(s) or total bromide(s). These latter two terms are used in the food additive tolerances (21 CFR 123) and raw agricultural commodities tolerances (40 CFR 180).

2. Chemistry

At room temperature, pure EDB is a colorless, heavy, nonflammable liquid. It is prepared commercially by reacting bromine with ethylene gas and has a characteristic mildly sweet odor detectable in air at levels ranging from 10 to 25 ppm (77 mg/m^3 to 192.5 mg/m^3). Its chemical formula is CH_2BrCH_2Br, its molecular weight is 187.88, and its structural formula is:



$$\begin{array}{ccccccc} & & Br & & Br & & \\ & & | & & | & & \\ H & - & C & - & C & - & H \\ & & | & & | & & \\ & & H & & H & & \end{array}$$

Table 1 lists other chemical and physical properties of EDB.

3. Uses and Registration

EDB has been produced in the United States since the 1920's and used primarily as a lead scavenger in leaded antiknock gasoline additives. Because of the Agency's regulations requiring a phase-out of leaded gasoline, this use of EDB has steadily dropped over the last few years and is expected to eventually become negligible.

During the 1950's and 1960's, federal pesticide registrations for uses of EDB as a fumigant were granted under FIFRA. Currently, the major registered pesticidal uses of EDB are:

- o Pre-plant soil fumigation by injection for a wide variety of food and non-food crops including vegetables, fruits, grains, peanuts, cotton, and tobacco;
- o Post-harvest commodity fumigation for grains, fruits and vegetables, including various State, Federal or international quarantine programs on citrus, fruits, nuts, and vegetables;
- o Fumigation of grain milling machinery and flour mills to control insect infestations in milling remnants and processed milled products.

Other uses of EDB include:

- o Control of wax moths in beehive supers;
- o Control of mountain pine bark beetles in the western states by Federal and State forestry agencies;
- o Control of drywood and subterranean termites in structural pest control operations;
- o Control of clothes moths, dermestid beetles and similar pests of furs, rugs, and other items in fumigation vaults; and
- o Control of Japanese beetles in the soil of balled ornamental trees and shrubs under the APHIS Quarantine Program.

EDB is usually formulated as a liquid concentrate or as a gel. There are 122 federal pesticide registrations, held by 53 registrants, of products containing EDB as an active ingredient, and 24 state registrations, held by 12 registrants. In addition, emergency exemptions for EDB use on soybeans (discussed in detail in the next section) were granted to six states early this year for use through the month of July, 1980. There are no Federally registered products containing EDB as an inert ingredient. Most of the registered products are mixtures of EDB and other active ingredients, such as carbon tetrachloride, ethylene dichloride, methyl bromide, chloroform, carbon disulfide, sulfur dioxide, chloropicrin, and benzene.

The Agency (Holtorf, 1980) estimates that about 340-360 million pounds of active ingredient EDB are produced annually in the U.S. by four basic producers: Dow Chemical, Ethyl Corp., Great Lakes Chemical and PPG

TABLE 2. EDB (Inorganic Bromide) Tolerances and Exemptions from Tolerance.

Commodity	Tolerance	Citation and Form
Soil Fumigation Uses		
Broccoli	75 ppm	40 CFR 180.126
Carrots	"	Inorganic bromides
Melons	"	(calculated as Br)
Parsnips	"	
Potatoes	"	"
Eggplants	50 ppm	"
Okra	"	"
Summer Squash	"	"
Sweet Corn	"	"
Sweet Corn Forage	"	"
Sweet Potatoes	"	"
Tomatoes	"	"
Pineapples	40 ppm	"
Cucumbers	30 ppm	"
Lettuce	"	"
Peppers	"	"
Cottonseed	25 ppm	"
Peanuts 1/	"	"
Asparagus	10 ppm	"
Cauliflower	"	"
Lima Beans	5 ppm	"
Strawberries	"	"
Post-Harvest (Commodity) Fumigation Uses		
Barley 2/	50 ppm	40 CFR 180.146
Corn	"	Inorganic bromides
Oats	"	(calculated as Br)
Popcorn	"	"
Rice	"	"
Rye	"	"
Sorghum (milo) 2/	"	"
Wheat	"	"

1/ 40 CFR 180.126(a) prohibits use of treated peanut hay and hulls as feed for meat and dairy animals.

2/ 40 CFR 180.1006 exempts these grains from the requirement of a tolerance for organic bromide residues of EDB.

Table 2 - continued

Commodity	Tolerance	Citation and Form
Quarantine Fumigation Uses		
Beans (String)	10 ppm	40 CFR 180.146 Inorganic bromides (calculated as Br)
Bitter Melons	"	
Cantaloupes	"	
Cavendish Bananas	"	"
Citrus Fruits	"	"
Cucumbers	"	"
Guavas	"	"
Litchi Fruit	"	"
Litchi Nuts	"	"
Longan Fruit	"	"
Mangoes	"	"
Papayas	"	"
Peppers (Bell)	"	"
Pineapples	"	"
Zucchini Squash	"	"
Cherries	25 ppm	40 CFR 180.146 Total inorganic and organic bromides
Plums (Fresh Prunes)	"	
Food Additive Tolerances		
Milled Grain Fractions	125 ppm	21 CFR 193.225 1977 Inorganic bromides (Calculated as Br) from all fumigation sources including grain-mill machinery.
Fermented Malt Beverages from corn grits and cracked rice	25 ppm	21 CFR 193.230 (d) (1977) Total inorganic bromides (calculated as Br) from all fumigations with bromine compounds.

Table 2 continued

Commodity	Tolerance	Citation and Form
Dried Eggs	400 ppm	21 CFR 193.250 Total inorganic bromides from all organic bromides used as a soil, commodity, or processed food fumigant (calculated as Br).
Parmesan and Roquefort Cheese	325 ppm	"
Concentrated Tomato Products	250 ppm	"
Dried Figs	"	"
Processed Foods (including processed grain and cereal products)	125 ppm	"
Milled Fractions in Animal Feeds from barley, corn, grain sorghum (milo), oats rice, rye, and wheat	125 ppm	21 CFR 561.260(b) Inorganic bromides (calculated as Br) resulting from carry over or concentration of residues from fumigation of grains with MBr or EDB.

Industries. The bulk of this production, about 230 million pounds, is used as a gasoline additive. Pesticide usage of EDB in comparison to total production is quite small, comprising about four percent or 13 to 15 million pounds of annual U.S. production. Estimates of quantities imported and exported for pesticide usage are considered confidential and are not publicly available. The major pesticide uses of EDB are dominated by agricultural soil fumigant use, comprising about 90% of U.S. consumption. The remaining 10% is used for commodity and space fumigation.

D. Regulatory History

1. Tolerances

There are no tolerances for EDB *per se* in or on raw agricultural commodities because it had been assumed, on the basis of data originally submitted by petitioners, that there would be no EDB residues. This conclusion was based on the hypothesis that the parent EDB compound had either completely evaporated or been converted to bromide ions which were subsequently taken up by plants as inorganic bromides. Residue analyses then available for EDB in crops grown in treated soil were negative for the organic molecule. The analytical method for organic bromide, employed from about 1950 through 1965, had a sensitivity of only 0.2 to 1.0 ppm and was not specific for EDB, but rather measured only the organic bromide ion. Consequently, tolerances were established in 40 CFR 180 for inorganic bromides resulting from the use of EDB in or on raw agricultural commodities, and as a food additive in processed foods by 21 CFR 193 and 561. These tolerances are presented in Table 2.

2. Pre-RPAR Actions

On October 16, 1974, the National Cancer Institute (NCI) issued a "Memorandum of Alert" describing a preliminary finding of EDB's carcinogenic activity in rats and mice. On the basis of this information,the Agency began a general review of the production and use status of EDB.

On July 14, 1975, the Environmental Defense Fund (EDF) petitioned the Agency to investigate EDB on a priority basis and to take suspension or cancellation action against the compound, as justified (Butler, 1975). In November, 1975, EDB was accepted by the Office of Special Pesticide Review as an RPAR candidate, based on the final NCI study which showed EDB to be carcinogenic in both rats and mice. After this initial petition, EDF amended and renewed its request for action against EDB under FIFRA on January 21, 1976, September 30, 1976, and August 26, 1977 (Hinkle, 1976, 1977).

Additional evidence for this referral included studies showing EDB to be mutagenic and capable of producing adverse reproductive effects in several species of animals. On September 7, 1977, the Agency's Carcinogen Assessment Group issued a Preliminary Risk Assessment for EDB which stated, "There is strong evidence that EDB is likely to be carcinogenic to man" (CAG, 1977).

Following intensive review and validation of the literature, the Agency published a Notice of RPAR and the RPAR Position Document 1 in the Dec. 14, 1977 *Federal Register*. The basis for the RPAR is the risks to man of oncogenicity, mutagenicity, and adverse reproductive effects as a result of pesticidal exposures to EDB.

3. Post-RPAR Actions

During the initial rebuttal period, December 14, 1977, to January 30, 1978, the Agency received twelve requests for extension of the rebuttal period. The Agency granted an extension to April 3, 1978. During and after the extended rebuttal period, 91 rebuttal submissions were received. After the extension deadline, several rebuttals were amended, resulting in a total of 105 documents in the rebuttal file (Appendix 1). Thirteen of these submissions contained rebuttal information alone or in combination with benefits information. Thirty-four of the submissions provided some type of benefits information only, while an additional thirty-five contained "testimonial" statements of need which were not supported by any data. There were several other submissions, including support for an immediate "ban" or other action against EDB.

Following the 1979 suspension of DBCP as a preplant pesticide for soybean nematode control, several states claimed that there are no other registered pesticides that are economical or effective against nematodes. Based on test results showing EDB to be as efficacious as DBCP, six states applied for temporary permits (e.g., exemptions from FIFRA) to allow this use under section 18(c) of FIFRA. These exemptions were granted for the period beginning April 24, 1980 and ending July 31, 1980, with numerous restrictions to reduce health risks to applicators. Table 3 describes these exemptions in detail.

II. Risk Analysis

The Agency issued the Notice of RPAR and Position Document 1 (PD-1) based on three criteria: oncogenicity, mutagenicity, and reproductive effects. After issuing the RPAR, the Agency began a detailed risk/benefit analysis according to applicable guidelines and policies. This chapter is divided into three sections: Section A evaluates the rebuttal comments the Agency received following the issuance of the PD-1, and discusses the scope and quality of the available toxicological data, including new data obtained since the publication of PD-1; Section B estimates human exposures; and Section C quantifies the potential health risks of EDB to humans.

A. Rebuttal Evaluations and Qualitative Assessment of Risk Data

1. Oncogenicity

In issuing the RPAR, the Agency relied on evidence of oncogenicity reported in an NCI-sponsored study (Weisburger, 1977). This study showed a statistically significant increase in the incidence of squamous cell carcinoma of the forestomach in both rats and mice as compared to the controls. Based on its preliminary review of the data from NCI, the Agency stated:

> .. EDB causes a significant increase in the incidence of gastric carcinomas in both sexes of rats and mice. Metastases of these tumors are reported. The tumor rates appear to be high and the differences are highly significant. (Anderson, 1977).

The Agency's position that an oncogenic rebuttal should arise is based on its evaluation of this study and 40 CFR Section 162.11(a)(3)(ii)(A). This statute states that rebuttable presumption of oncogenicity shall arise if a pesticide "... induces oncogenic effects in experimental mammalian species or in man as a result of oral, inhalation or dermal exposure..." As a further clarification of the provision, the preamble to the Agency's Interim Procedures

Table 3. Emergency Exemptions for EDB Use on Soybeans (4/24/80-7/31/80)

Location of Use/Applicant	Pest	Acreage (Maximum)	Product
Alabama/Department of Agriculture and Industries	Soybean Cyst Nematode Root-Knot Nematode	160,000	Soilbrom 90EC
Florida/Department of Agriculture and Consumer Services	Soybean Cyst Nematode Southern Root-Knot Nematode Peanut Root-Knot Nematode Reniform Nematode String Nematode	130,000	Soilbrom 90EC
Georgia/Department of Agriculture	Soybean Cyst Nematode Peanut Root-Knot Nematode Lance Nematode	98,000	Soilbrom 90EC Dow Fume W-85 Ethylene Dibromide
Mississippi/Department of Agriculture and Commerce	Soybean Cyst Nematode Spiral Nematode	5,000	Soilbrom 90EC
South Carolina/Clemson University	Columbia Lance Nematode	1,000,000	Soilbrom 90EC Dow Fume W-85 Ethylene Dibromide
Tennessee /Department of Agriculture	Soybean Cyst Nematode	2,118,818	Soilbrom 90EC

Restrictions on use for all above exemptions include:

1. Application rate may not exceed 32 lbs/acre/year of EDB active ingredient
2. Application is to be carried out in accordance with the supplemental labeling submitted on April 1, 1980, except use must be limited to pests authorized by this exemption.
3. Applicators and others handling EDB must wear protective clothing and a respirator, unless a "closed system" is used, which prevents applicator contact with EDB.
4. All applicable precautions and restrictions on the registered product label are to be observed.
5. No more than the acreages designated above are to be treated.
6. Soybean hay from treated fields may not be used for feed.
7. Residues of inorganic bromide must not exceed 125 ppm in or on soybeans or 150 ppm in soybean meal. Soybeans with less than 125 ppm and soybean meal with less than 150 ppm inorganic bromide residues may be moved in interstate commerce. The Food and Drug Administration, DHEW, has been notified.

and Guidelines for Health Risk and Economic Impact Assessment of Suspected Carcinogens (May 25, 1976; 41 FR 21402) states that "... a substance will be considered a presumptive cancer risk when it causes a statistically significant excess incidence of benign or malignant tumors in humans or animals."

On the basis of the evidence summarized in Position Document 1, the Agency concluded that the cancer risk criteria had been exceeded by all registrations and applications for registration of pesticide products containing EDB, and that a rebuttable presumption against new or continued registration of such products should arise.

Six respondents (Rebuttal nos. 3C, 47, 48, 64, 78 and 79) addressed rebuttal comments to the oncogenic criterion. The Agency has divided these rebuttals into two broad groupings, those which address uncertainties in extrapolating to man from the laboratory studies conducted on animals, and those studies which investigate the health of workers occupationally exposed to EDB.

a. Response to Rebuttals of Animal Oncogenicity

(1) Direct Response to Rebuttals

The comments addressing the uncertainty of extrapolating from animals to man can be grouped into broad categories:

- The route of administration, intubation, was inappropriate because human exposure would be primarily by inhalation;

- Massive doses both obscured detection of a no observable-effect-level (NOEL) and overwhelmed the animals' metabolic and detoxification processes;

- The forestomach, where tumors occurred in the test animals, is without a counterpart in humans;

- The oncogenic response at the site of intubation was due to an extreme irritant effect.

The Agency has concluded that the first rebuttal listed above is invalid. Human exposures to EDB also result from its presence in the human diet. At least three uses of EDB result in its presence in the human diet: fumigation of stored grains; "spot" fumigation of grain milling machinery; and postharvest fumigation of citrus, tropical fruits and vegetables.

In addition, the latter part of this section describes recent evidence which demonstrates that EDB is a potent carcinogen in animals following inhalation exposure. Midwest Research Institute (MRI), under a contract with The National Institute of Occupational Safety and Health (NIOSH), found a significant increase in the incidence of tumors of the spleen, mammary gland, adrenals and subcutaneous tissues in a group of rats exposed to 20 ppm of 1,2-dibromoethane alone (Wong, 1979). Most recently, Hazelton Laboratories, under a contract with NCI (1980), also found inhalation of EDB to be causal to a statistically significant increased incidence of cancers in both rats and mice.

The second rebuttal comment, that the massive doses overwhelmed the animals' metabolic systems, obscuring a no-observable-effect-level (NOEL), is one of the most common criticisms of NCI cancer bioassay studies (Mishra, 1978a). It has been argued by the Agency (Mishra, 1978a) and NCI that the use of maximum tolerated dose (mtd) and 1/2 maximum tolerated dose in cancer bioassay (even in the absence of a NOEL) is now accepted by the Agency, and its use has been included in the proposed EPA/OPP oncogenicity testing guidelines. Results from the above-mentioned NCI study (1977) show that mice receiving only 1/2 the mtd experienced extremely high and statistically significant cancer incidence. In addition, results from the NIOSH and NCI-sponsored studies discussed above demonstrate that EDB is carcinogenic in animals at low doses (20 ppm). The Agency's Interim Cancer Guidelines (41 FR 21402) state that in the absence of definitive information to the contrary, any exposure, however small, will incur some risk of cancer on the exposed population. In essence, the Agency position is that there is an assumed cancer risk from chemical carcinogens for any level above zero. The Agency concludes that this rebuttal is invalid.

The Agency also concludes that the third rebuttal is not valid. It is true that humans do not have a counterpart to the forestomach of rats. "However, the site of tumorigenic effect, and the tumor cell type produced by a chemical is known to change depending upon the animal species, dose schedule and routes of administration used. Thus, the absence of forestomach in humans may not make humans immune to carcinogenic effects of EDB." (Mishra, 1978a). This rebuttal is further invalidated by results of the NIOSH study in which inhaled EDB was found to induce tumors of the spleen, mammary gland, adrenals, and subcutaneous tissues.

The fourth rebuttal, that the oncogenic response was due to an extreme irritant effect, is based on the chronic "irritation" theory of carcinogenesis. This general theory that there is high correlation between chemicals which are irritants and are also carcinogens has long been discarded and the evidence against it is summarized in the book Carcinogenesis as a Biological Problem (Berenblum, 1974). Most irritants in mouse dermal tests were noncarcinogenic and the same was true for irritants introduced in subcutaneous and other types of exposure tests. Among the carcinogens which could be described as irritants, there was no correlation between carcinogenic potency of the agent and the degree of irritant injury produced.

(2) Pertinent New Studies

Since the issuance of PD-1, three new studies were completed which investigated the carcinogenic potential of EDB in animals. These are the Dow Chemical Company Rat Inhalation Study, the Midwest Research Institute Rat Inhalation Study, and the NCI Rat and Mouse Inhalation Study.

Dow Chemical Co. Rat Inhalation Study: A final report entitled "13 Week Repeated Inhalation Study on Ethylene Dibromide (EDB) in Male and Female Rats" (Nitschke, 1980) was reviewed by the Agency (CAG, 1980b). The study consisted of exposing male and female CDF (F-344) rats to 0, 3, 10 or 3076 mg/m^3 ethylene dibromide, 6 hours/day, 5 days/week for 13 weeks for a total of 67-68 exposures in 95-96 days. Scheduled sacrifices occurred after 1, 6, and 13 weeks of exposures.

Findings from the study included:

- rats exposed to 23 mg/m^3 EDB showed no consistent effect in any parameter;
- at 77 mg/m^3 EDB caused slight epithelial hyperplasia of the nasal turbinates in animals necropsied after 1, 6 or 13 weeks of exposure; however, 88 days after the last exposure to EDB, no morphological difference from control animals was observed;
- rats exposed to 3076 mg/m^3 EDB showed a definite adverse response characterized by a decrease in body weight gain, an increase in liver and kidney weights, and pathologic effects in the nasal epithelium. The nasal turbinates of rats progressed from very slight hyperplasia of the epithelium to hyperplasia and nonkeratinizing squamous metaplasia.

The Dow report concludes:

While this study has shown that repeated subchronic exposures of rats to 77 mg/m^3 or 3076 mg/m^3 EDB induce pathologic changes in respiratory epithelium of the nasal turbinates, a subsequent post-exposure phase revealed a lack of progress of the lesions with almost complete reversions toward normal histologic appearance of the nasal turbinates. In view of these findings and the lack of any lesions subsequent to repeated exposure to 3 ppm EDB, short-term repeated exposure to these concentrations of EDB would not be expected to result in any long term irreversible effects upon the nasal turbinates or other tissues of the body.

The Agency (CAG, 4/30/80) has reviewed this study, noting the short duration of exposures, and has concluded that this study involved exposures to animals which are clearly too short in exposure duration to be of value in determining chronic risks present from long term exposures to EDB. (CAG, 1980b).

Midwest Research Institute Rat Inhalation Study (Wong, 1979): This study involved significantly longer exposures and lower concentrations of EDB. This 18 month study with Sprague-Dawley rats was designed to assess the carcinogenicity of inhaled ethylene dibromide (EDB) and the effect of dietary disulfiram on the carcinogenic response to ethylene dibromide. For this purpose, the tumor response of four groups of males and females, each with a size ranging from 120-134 animals was evaluated as follows: (1) controls; (2) 154 mg/m^3 of inhaled EDB administered for 7 hrs/day, 5 days/week for 18 months; (3) 0.05% disulfiram in the diet for 18 months, and (4) both EDB and disulfiram.

The preliminary draft report was reviewed by the Agency (CAG, 1979). The project officer, Dr. H. B. Plotnick, stated that although the report is in draft form, the pathological data have been thoroughly reviewed and will not be altered in subsequent versions. The CAG analysis states that, this report permit us to make a direct estimate of the carcinogenic effect of inhaled EDB and frees us from having to rely on the unsatisfactory upper bound estimates previously derived from intubation studies.

The authors of the MRI report found that EDB alone (group 2) and EDB with disulfiram (group 4) produced a statistically significant increase in tumors at several sites, compared to the group of controls. The sites are listed below.

	EDB		EDB & Disulfiram	
	Males	Females	Males	Females
Spleen hemangiosarcoma	*	*	*	*
Adrenal tumors	*	*	*	*
Liver hemangiosarcoma	X	X	X	*
Liver hepatocellular carcinoma	X	X	*	*
Mesentery hemangiosarcoma	X	X	*	*
Kidney renal tumor	X	X	*	*
Subcutaneous tumors	X	X	X	X
Thyroid tumors	X	X	*	*
Mammary tumors	-	*	-	*
Lung tumors	X	X	*	X

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* denotes statistically significant increase, $p<0.05$

X denotes not statistically significant

- not applicable

Thus, this study demonstrates that EDB is also carcinogenic in rats following prolonged inhalation exposures. "A high mortality rate and a significant increase in the incidence of tumors of the spleen, mammary gland, and adrenals was noted in the group [of rats] exposed to 154 mg/m^3 1,2-dibromoethane alone." (Plotnick, 1980).

National Cancer Institute Rat and Mouse Inhalation Study (NCI, 1980): The possible carcinogenicity of 1,2-dibromoethane in rats and mice was tested by Hazelton Laboratories of America, Inc., and published recently in a cancer bioassay under a contract sponsored by the National Cancer Institute (NCI).

In the rat study, 50 F344 rats of each sex were exposed to 77 or 3076 mg/m^3 of 1,2-dibromoethane by inhalation 6 hours/day, 5 days/week for a maximum of 103 weeks. Untreated control groups comprised of 50 rats of each sex were exposed in chambers of ambient air.

The body weights of the rats were monitored throughout the study. The mean body weights of the high exposure group of either sex were lower than those of the corresponding untreated controls. Survival periods in the high-dose rats of both sexes were shorter than in the controls.

The histopathologic examination of all the major tissues and organs revealed a statistically significant increase in the incidences of carcinomas, adenocarcinomas, adenomatous polyps of the nasal cavity, and hemangiosarcomas of the circulatory system in male and female rats exposed to a 3076 mg/m^3 dose level as compared to the controls.

In addition, a statistically significant increase in tumor incidences of the following organs of rats was observed: adenomas of the pituitary in low-dose rats of either sex when compared with the corresponding controls; and alveolar/bronchiolar adenomas or carcinomas and fibroadenomas of the mammary gland in high-dose female rats when compared with the corresponding controls.

In summary, 1,2-dibromoethane was carcinogenic for F344 rats. These results confirm the carcinogenic effect observed in the NIOSH study in Sprague-Dawley rats tested by Midwest Research Institute.

In the mouse study, fifty B6C3F1 mice of each sex were exposed to 77 or 3076 mg/m^3 of 1,2-dibromoethane by inhalation 6 hours/day, 5 days/week, for a minimum of 78 weeks. Untreated control groups consisting of 50 mice of each sex were exposed in a chamber to ambient air. Throughout the study, mean body weights of high-dose mice of either sex were lower than the controls. Survival of the low and high-dose female mice was significantly shorter than survival for the corresponding controls.

The histopathologic examination of all major organs revealed statistically significant incidences of alveolar/ bronchiolar adenomas or carincinomas in high-dose male mice as compared to the corresponding controls. In high-dose female mice, the incidences of hemangiosarcomas of the circulatory system, fibrosarcomas of the subcutaneous system, carcinomas or adenomas of the nasal cavity, and adenocarcinomas of the mammary gland were significantly higher than those in the corresponding controls.

In summary, 1, 2-dibromoethane induced a carcinogenic effect in male and female B6C3F1 mice. The Agency (CAG) will extensively review this study and evaluate data for possible use in the quantitative risk assessment for human population exposure to 1,2-dibromoethane via inhalation.

(3) Conclusion - Animal Oncogenicity of EDB

On the basis of the discussion presented above, the Agency concludes that the presumption of oncogenic risk as stated in PD-1 has not been rebutted, because no respondent to that notice has sustained the affirmative burden of proof set forth in 40 CFR 162.11(a)(4). In providing an assessment of the "weight" or meaning of the available studies on oncogenicity of EDB to animals, the Agency concludes that EDB is a potent animal oncogen.

b. Response to Rebuttals of Human Oncogenicity of EDB:

In response to the human oncogenic potential of EDB, one respondent (Rebuttal No. 3c) submitted three studies which investigated the health of workers exposed to EDB. Each of these studies is summarized below, together with the Agency evaluation.

(1) The Mortality Experience of 161 Employees Exposed to Ethylene Dibromide in Two Production Units (Ott,1977)

This study was undertaken to investigate the mortality experience of persons occupationally exposed to EDB in two manufacturing units. The emphasis of the study was on cancer mortality and cancer due to respiratory disease. The total cohort population consisted of 161 employees from both units.

The estimated EDB exposure and duration of exposure ranged from 1-96 ppm and 1-16 years respectively. In both Units I and II, employees were also exposed to several other potentially toxic chemicals, such as vinyl chloride, carbon tetrachloride, benzene, nickel acetate and silica. The study did not mention the exposure levels or duration of exposure of employees to these and numerous other chemicals. In addition, a number of employees in Unit II were exposed to arsenic, a known carcinogen.

The investigators reported that no increased malignancy was noted in Unit I. The observed cancer incidence was 1 case against 3.6 expected. The deaths from all causes were not elevated over expected deaths. In Unit II, after excluding the workers exposed to arsenic, a slight increase in both cancer deaths and deaths due to respiratory diseases were observed. A total of 5 cases of malignant tumors were observed in contrast to the expected incidence of 2.2 ($p=0.072$). Two of these 5 cases were stomach cancers against an expected incidence of 0.7 ($p = 0.150$). The remaining 3 cancer cases were also higher relative to 0.9 cases expected ($p = 0.063$). The investigators concluded that, because of the limited size of the study population and the variety of toxic agents to which individuals in Unit II may have been exposed, it would be difficult to interpret these findings as being demonstrative of effects of EDB specifically, or any other specific toxic agent.

In submitting this study, the rebuttors noted that it was of doubtful significance (Great Lakes Chemical Co., 1977). The Agency has concluded the following:

"This study shows slight increases in stomach cancer incidence and deaths due to all causes; however, this may not be solely attributed to EDB exposure alone, since workers were also exposed to other chemicals, and that two cancer deaths occured in the same family (father and son)." (Mishra, 1978a)

(2) The Associated Octel Company Ltd: A Mortality Survey on Employees at an Ethylene Dibromide Plant at Hayle, England (Turner, 1977)

The study investigated the death rates of 117 persons occupationally exposed to EDB where employment was known to exceed 4 years. Rates per 1000 man years were compared between EDB workers and the population of southwest England. The number of man years in the four groups in the age range of 25 to 44, 45 to 64, 65 to 74, and 75 and over, were 1797, 1440, 177, 67 respectively. The author claims that when these groups were compared with the population in southeast England, there was no observed increased incidence of cancer deaths in the workers exposed to EDB.

No monitoring or exposure levels of EDB in the plant are discussed. Without knowing the exposure levels of EDB, the Agency is unable to use this study to assess the human oncogenic potential of EDB. (Mishra, 1978a).

(3) Dibromoethane: A Survey of Employee Records at Amlwch Factory (Turner, 1976).

This study was a retrospective investigation of the mortality experience of workers occupationally exposed to EDB at a manufacturing plant in southwest England. The health records of the personnel employed at the factory during the period from 1952 to 1975 were examined. These employees were an unusual group, in that they were preselected for employment on the basis of above average health. Of the 297 employees known to have worked at the site, a cohort of 273 persons was accounted for and used in the study.

Ambient air levels of EDB in the plant were not given. Although the duration of exposure of the entire cohort was not determined, the investigators reported that the 31 men, who died by the end of 1975, had worked on the site an average of 13 years.

The average age of the group was 40 years. Mortality rates for the entire cohort were calculated and were compared to the death rate for males in an unexposed population in the 45-64 age group in the area in which the Amlwch Factory was located. The average ages of the test and control groups differed. It was the researcher's opinion that this would provide the most significant evidence of any association between EDB exposure and increased morbidity.

The investigators determined that among the workers who died, the incidence of deaths due to all causes as well as heart disease, cardiovascular disease and cancer of various sites was in most cases lower than the control group (45-64 years of age), or approximately the same as the control group. The author attributed this lower death rate to the preselection of healthy workers prior to employment. The authors concluded that, "it is difficult to conclude from the data on this relatively small group of persons who have had regular slight exposure to dibromoethane that there is any association between such exposure and any particular disease."

The Agency agrees with the investigators, and also finds that it is difficult to conclude that there is no EDB exposure-related cancer death in the workers. (Mishra, 1978a)

(4) Conclusions-Human Oncogenicity of EDB

Based on the evaluation of the rebuttals discussed above, the Agency concludes that, because no respondent has sustained the affirmative burden of proof set forth in 40 CFR 162.11(a)(4), the presumption of oncogenic risk to humans has not been rebutted. The Agency concluded that the latter two studies conducted in England are not useful in evaluating the human health risk of exposure to EDB. The Agency (CAG, 1978) considers only the first study listed above as technically acceptable. Though it did not show a statistically significant cancer incidence in exposed workers, the Agency concludes that the animal data provide substantial evidence that EDB is a likely carcinogen for humans.

2. Mutagenicity

In PD-1 the Agency evaluated all of the available studies on the mutagenic potency of EDB. These studies, summarized in Table 4, tested EDB for three types of mutagenic effects: point (gene) mutations, chromosomal aberrations and primary DNA damage. Each of these categories was further subdivided into positive or negative mutagenic effects. These are the conclusions reported in the PD-1:

> "In a memorandum dated 9-10-77, Dr. R. Pertel stated that there is ample evidence to fulfill both the multitest criteria for EDB as a mutagen as well as the scientific criteria of EPA's Science Advisory Board's (SAB) study group on mutagenicity. This evidence shows EDB to be positive in both prokaryotic (microbial) and eukaryotic (higher forms including mammals) for point (gene) mutational effects, with and without mammalian metabolic activation." (December 14, 1977; 42 FR 240, page 63141)."

40 CFR 162.11(a)(3)(ii)(A) states that a "... rebuttable presumption shall arise if a pesticide's ingredient(s)... induces mutagenic effects as determined by multitest evidence." Further, Section 162.3(4) defines the term mutagenic as "... the property of a substance or mixture of substances to induce changes in the genetic complement of either somatic or germinal tissue in subsequent generations." Based on the induction of point mutations by EDB in several tests, the Agency concluded that the mutagenic risk "... index has been exceeded by all registrations and applications for registration of pesticide products containing EDB, and that a rebuttable presumption against new or continued registration of such products has therefore arisen." (December 14, 1977, 40 FR 240, page 63135).

a. Mutagenicity Rebuttals

Four respondents submitted rebuttals specific to this presumption of the mutagenic risk of EDB (rebuttal nos. 3c,47,48,64). Rebuttal comments included general arguments about the mutagenicity testing systems used and specific statements about the studies reviewed in PD-1. These rebuttals, together with the Agency's scientific review and evaluation, are summarized and responded to in this section. Mutagenic studies on EDB which have become available since the EDB PD-1 was issued are also evaluated.

(1) General Comments

The rebuttals which relate to the mutagenicity RPAR express four general areas of concern: the significance of the testing systems; the limitations of the tests on EDB; available information; and the validity of specific studies.

(a) Significance of Mutagenicity Tests

The Great Lakes Chemical Corporation (Rebuttal No. 3C) and the Hopes Company (Rebuttal No. 64) questioned whether in vitro (or "test tube") tests indicate a potential for in vivo mutagenicity or carcinogencity:

> "While EDB has produced some mutations in in vitro testing, the significance of these results in assessing the mutagenic or carcinogenic risks of EDB is not established and subject to serious scientific debate." (Rebuttal No. 3C).

Ethyl Corporation (Rebuttal No. 48) also questioned the predictive utility of existing test systems. They mentioned microbial, insect, and cell culture studies which require extrapolation of results to apply to humans: "...The ability of EDB to induce mutations in a variety of test systems is only suggestive of its potential to induce mutations in the human population..." and "...there is no evidence to determine the relative risk..." (Rebuttal No. 48).

In response, the Agency supports the mutagenicity studies of non-human test systems. Data from non-mammalian test systems are relevant in considering the potential mutagenicity of a compound. In the absence of adequate mammalian systems which are sensitive enough to exhibit the many mechanisms of possible genetic damage in reproductive cells, other test systems are utilized to expose the chemical's intrinsic capacities to alter genetic components. This evidence has generated a presumption of hazard as stated in the PD-1.

Table 4 Summary of Mutagenicity Testing of EDB

Genetic Event and Test System	Species/Strain/Type	Concentration or Dose	Genetic Indicator or Effect	Result	References
Gene (Point) Mutation					
Bacterial, *In vitro*	*Salmonella typhimurium* *his G 46* TA 1530, 1535, 100	10-10,000 ug (10 ul)/ plate	Reversions by Base-Pair Substition	Positive w/o MA[1]	(Brem, et. al, 1974) (Buselmaier, et al, 1972) (McCann, et al. 1975)
Bacterial, Host-Mediated Assay (mouse)	*S.typhimurium* G 46/*his*	500 mg/kg i.m. to mouse	Reversions	Positive	(Buselmaier, et.al, 1972)
Eukaryotic Microbial, *In vitro*	*Neurospora crassa* *ad -3*	1.2-1.63 ul/ml	Recessive Lethals	Positive w/o MA	(De Serres, at al, 1970) (Malling, 1969)
Insect, *In vitro*	*Drosophila melanogaster* males	0.3 mM fed ad. lib. 3 days	Sex-linked Recessive Lethals	Positive	(Vogel, et al, 1974) (early germ cells affected)
Somatic Cell Culture *In vitro*	Mouse Lymphoma cells L5178y TK Heterozygotes	1.0-3.0 mM for 2, hours	Induction of TK Homozygotes	Positive (dose response)	(Clive, 1973)
Higher Plants	*Tradescantia*, Mutable Clones	3.6 - 222.9 ppm (gas)	Stamen Hair Color (blue to pink)	Positive (dose response)	(Nauman, et al 1974;;Sparrow *et al*.)
Higher Plants	Barley Seeds	0.1-1.1 mM	Chlorophyll Mutations	Positive at LD_{50}	(Ehrengerg, *et al., 1974*)
Bacterial, In vitro	S. typhimurium his G 46 TA 1538	11.5 uM 19 ul/plate	Reversions by Frame-Shift	Negative w/o MA	(Brem, et al, 1974)
Bacterial, In vitro	S. typhimurium LT 2 gal-chl A	5 ul/plate	Deletions	Negative w/o MA	(Alper, et al, 1975)
Bacterial, Host-Mediated Assay (mouse)	*S. marcescens* $\overline{A}$ 21/*leu*	500 mg/kg i.m. to mouse	Reversions	Negative	(Buselmaier, et al., 1972)

1/ w/o MA= without metabolic activation

Experimental animals are utilized throughout the various disciplines of toxicology to predict adverse effects and the probability of inducing certain effects in humans for a given range of doses of a compound. Certainly there exist numerous examples of cases where humans did not display the anticipated effect predicted from animal studies. Humans have also shown effects not demonstrated in the experimental studies, or have been more or less susceptible than the non-human species. However, the theorum that "the basic biological mechanism explored and documented in experimental studies with non-human subjects is valid when extrapolated to humans to predict risk," still holds firmly, as evidenced by the universal acceptance of non-human experimentation in science. (Chaisson, 1978)

Predicting potential of a compound to induce mutagenic effects in humans is more difficult than predicting other types of toxicities, but the logic can still be founded on establishing the mechanism in appropriate non-human species. This concept is discussed at length in the DHEW document by the Subcommittee on Environmental Mutagenesis, 1977. Valid studies demonstrating mutagenic effects in experimental animals, and the mechanisms of those effects, coupled with serious consideration of pharmacologic principles and biodistribution in humans do establish the framework for presuming a mutagenic hazard to humans. The evidence of mutagenic potential in non-human species can be used to predict potential for humans.

The application of test results was addressed by the Great Lakes Chemical Company: "...None of the test systems used were capable of detecting anything other than short-term effects of a mutagen. The same applies to the evaluation of the genetic risk." (Rebuttal No. 3C).

The philosophy summarized above has been considered by EPA and is addressed in the document by the DHEW Committee to Coordinate Toxicology and Related Programs, 1977. The problems in definitively identifying human mutagens are recognized. However, interpretation of the available test results with the pharmacokinetic and biochemical considerations, and matching of results of reproductive studies can give presumptive evidence on which hazard to humans can be predicted and regulatory decisions contemplated (Chaisson, 1978).

Great Lakes Chemical Co. expressed a related point: "Even an established human mutagen is not likely to have any mutagenic effect unless the exposure reaches the testes or ovaries." (Rebuttal No. 3C).

The Agency agrees completely with this statement. It is obvious that in order to have a heritable effect, the mutagen must reach the reproductive tissue. As discussed in the next section, the available reproductive studies provide evidence that the reproductive tissues in exposed animals can be adversely affected by EDB.

(b) Limitations of Available Tests

Hopes Company states that there is a necessity for a multitest approach to mutagenicity testing, with strong emphasis on those tests which relate directly to man, and that the only real way to test for heritable mutation in man is to utilize a test system with guidelines from the DHEW document "Approaches to Determining the Mutagenic Properties of Chemicals: Risk to Future Generations." The Agency agrees with the principle set forth in this document that a multiple-system approach is necessary since no single adequate test exists. Hopes Company has outlined the optimal criteria, but has failed to cite what the species and test protocol would be. The Agency recognizes the shortcomings of each test system but also the utility of the tests when they are considered as a group.

(c) Validity of Specific Studies

The Douglas Chemical Company criticized the Buselmaier, 1972 study: "Response data indicated the data presented are insufficient for evaluating the effect of EDB in the host-mediated assay with S. marcescens, since results of only a single dose were reported." (Rebuttal No. 47).

The Agency agrees that an ideal protocol in the host-mediated test would include at least three dosage levels, with at least ten animals per dose level. Utilization of a different protocol tempers the resulting strength of conclusions, but does not nullify the fact that the 500 mg/kg dose (subcutaneous) increased the mutation frequency over the control group by a factor greater than eight.

The rebuttor also rejected the use of the inconclusive results of Epstein et al., 1972, to support the RPAR. The rebuttor's reasons for this position were unclear. The Agency did not use this study to support the presumption of hazard; the study was mentioned to establish that it was considered, but that the results were inconclusive.

In addition, the rebuttor disagreed with EPA's rejection of the results ofBrem, (1974) and implied that the single dose used in the study was evidence of no mutagenic potential. The rebuttor's position is not adequately developed. EPA has considered this study to be invalid because no information on the effective dose or range is given. Also, the strain used, S.typhimurium TA 1538, would not be expected to predict activity since this strain is designed to detect frameshift mutagens and EDB is more likely to cause base-pair substitution mutations. The rebuttor's position does not rebut the RPAR presumption.

b. Agency Position on Mutagenicity Rebuttals

The Agency has reached the following general conclusion on all the rebuttals submitted in argument against the Agency's position in PD-1:

"The methodology currently used in mutagenesis assay studies has been generally accepted on theoretical grounds and offers the only means to predict adverse genetic effects in humans." [and] "The comments in the Rebuttal Nos. 3C, 47, 48 and 64 underscore the limitations of these test systems but do not rebut the Agency's presumption of hazard as outlined in the RPAR document." (Chaisson, 1978).

Thus, the Agency concludes that the mutagenic risk as stated in the RPAR Notice has not been rebutted, since no respondent to that Notice has sustained the affirmative burden of proof set forth in 40 CFR 162.11 (a)(4).

c. Re-evaluation of Mutagenicity Data and Review of New Studies

In the light of recent research, the Agency has re-evaluated the mutagenicity data presented in the RPAR Notice and reviewed additional studies as to the mutagenic potential of EDB.

In the PD-1 the Agency concluded that "no positive chromosomal damage studies have been found for EDB." After a review of the study by Ehrenberg, *et al* ., (1979), the Agency (Mauer, 1979) has concluded that, in addition to the point (gene) mutations cited in the PD-1, this study also demonstrates that EDB causes chromosome-damaging effects as discussed below.

EDB was shown to cause chromosome exchange in barley seeds which were treated with 1.4 mM of EDB for 24 hrs. Cells were analyzed for chromosomal aberrations in the first mitosis following treatment. The observed frequencies of induced chromosomal aberrations were determined to be significantly higher than the control material.

Additional studies, not available at the time of the RPAR Notice, have since been reviewed by the Agency (Mauer, 1979). These studies lend additional support to the Agency's position that there is multitest evidence indicating that EDB induces mutagenic effects in laboratory test systems. The studies cited below all show positive effects. They are discussed according to the specific genetic indicator involved, i.e.: (1) point (gene) mutation; (2) chromosomal aberration; (3) primary DNA damage.

(1) Point (gene) mutation

EDB at concentrations as low as 0.2 parts per million has been shown to induce sex-linked recessive lethal mutations in *Drosophila melanogaster* (Kale and Baum, 1978). Early germinal stages were affected at a rate 3 times as great as the spontaneous mutation rate, indicating that even lower concentrations could cause mutagenic effects.

EDB has also been shown to cause reverse mutations in *Aspergillus nidulans* and *Escherichia coli* as well as induction of ochre suppressors in *E.coli* (Scott, B.R., *et al* , 1978). The potency of EDB was shown to increase with metabolic activation by a plant extract of *Tradescantia* clone 4430.

(2) Chromosomal damage

EDB produced micronuclei in tetrads of microsporogenesis of *Tradescantia* clone 4430 by a 6-hour treatment with 20-160 ppm of EDB gas (Ma, et al., 1978). A range of 0.001-0.002 micronuclei/tetrad/ppm-hr. was established by dose-effect experiments.

(3) Primary DNA damage

EDB was shown to indirectly interact with nucleophilic sites and strongly inhibit RNA transfectivity via the production of "half-mustards" (Kondorosi, et al., 1973). Q -RNA was inactivated by EDB in the presence of thioglycol after treatment for 1 hr. in a phosphate buffer.

These recent studies, not available at the time PD-1 was issued, reaffirm the results of earlier citations and indicate that in addition to causing point (gene) mutations and primary DNA damage, EDB possesses chromosome-damaging effects as evidenced by several *in vitro* assays.

An additional study investigating the potential mutagenicity of EDB in the rat and mouse has been reviewed by the Agency. The study, an investigation of dominant lethal mutations, concluded that EDB at a dosage of 10 or 30 mg/kg in mice and 100 or 150 mg/kg in rats did not induce dominant lethal mutations in either of the species (Teramoto, *et al.*, 1980).

It is the Agency's position (Mauer, 1979) that the negative results of this test are no indication of other genetic events which can occur as a result of the transport of EDB or its metabolites to mammalian germ cells. The genetic end-point of this test is gross chromosomal damage, a relatively insensitive and limited indicator of total genetic damage. This test does not detect the variety of genetic damage demonstrated in the other test systems reviewed by the Agency. Thus, the Agency concludes that this study is of very limited significance as compared to positive mutagenicity assays on EDB in multiple test systems.

d. Conclusions

Based on the evaluation of the rebuttals and new studies discussed above, the Agency concludes that no respondent has sustained the affirmative burden of proof set forth in 40 CFR 162.11(a)(4), and that the presumption of mutagenic risk to humans from EDB has not been rebutted. The Agency (Mauer, 1979) states:

> "Sufficient evidence exists to indicate EDB presents a potential mutagenic risk for humans, especially for individuals exposed to the relatively high levels of the chemical measured in occupational settings, such as during soil application and commodity fumigation. In summary, the evidence is as follows:
>
> o EDB is a potent mutagen, producing a broad spectrum of mutational events in submammalian *in vitro* systems, higher plant, and mammalian cell cultures.
>
> o EDB is mutagenic to germ cells *in vivo*, as shown by the sex-linked recessive lethal test in *Drosophila*, including significant increases in lethals in a dose-dependent fashion.
>
> o Notwithstanding the removal of a major portion of EDB administered experimentally to mammals, EDB is transported to mammalian germ tissues in amounts sufficient to produce significant effects as indicated by spermatogenic effects in bulls and rats. In addition, tissue distribution studies show measureable [sic] amounts can be transported to testicular tissue which may result in an accumulation of genetic lesions induced by this bifunctional alkylating agent. "(Mauer, 1979).

In regard to the suitability of the data to support a quantitative estimate of mutagenic risk, the Agency asserts:

> "Although there is a strong indication of risk at current levels of occupational exposures, the present data base does not permit quantification of mutagenic risks from the levels of EDB exposure likely to be encountered by the general population. As discussed by an EPA consultant...no coherent body of relevant data is available which could either be used to relate human EDB exposure directly to mutagenic events in any mammalian test system, or from which dose-response relationships can be extrapolated to humans. Further, previous indirect attempts to quantify risk from mutagenic studies in Drosophila did not take into account differences in mutational responses between ionizing radiation and many chemical mutagens... Also, there are basic differences in transport mechanisms between mammals and Drosphila which can affect the pharmacokinetic disposition of chemicals, especially via the inhalation route of exposure.
>
> Experimental work is currently in progress for estimating the mutagenic risk of EDB... patterned after studies already published on EMS... This approach will attempt to overcome the previous shortcomings of quantitative risk estimation mentioned above by utilizing a common unit of 'dose' to the germ lines of both Drosophila and male mice exposed to radioactive-labeled EDB. This 'dose' is defined as the amount of chemical bound to germinal DNA and is measured as the number of alkylations per DNA-nucleotide. The 'dose'-mutation curve in Drosophila will be compared to the exposure-'dose' curve in the mouse. In this way it may be possible to derive a quantitative estimate of the genetic hazard to humans from a given concentration or exposure level of EDB, since one could estimate the dose (as alkylations) to mammalian germ cells from given body exposures, and the genetic consequence of that dose in the Drosophila test." (Mauer, 1979).

3. Reproductive Effects

In Position Document 1 (PD-1), the Agency cited several studies in bulls and rodents which established that EDB could adversely affect mammalian reproductive development by interfering with the production of male gametes and the development of embryos. Adverse effects in hen egg production were also noted. In summary, the animal studies reported the following effects:

> Bulls - reduced sperm production; reduced sperm motility; and abnormal sperm structure. (Amir, 1973; Amir and Lavon, 1976; Amir and Ben-David, 1973)
>
> Rats and mice - selectively damaged spermatogenic cells resulting in "transient" sterility; decreased fetal implants and fetal weight. (Edwards et al., 1970; Short et al., 1976)
>
> Chicken Egg Production - reduced egg weight; reduced egg production; reduced fertility; generalized reduction in the permeability of ovarian membranes. (See Table 9, of PD-1)

An Agency Working Group concluded that the reproductive effects studies met the RPAR risk criterion stated in 40 CFR 162.11 (a)(3)(ii)(B), that a rebuttable presumption shall arise if a pesticide "produces any other chronic or delayed toxic effect in test animals at any dosage...which is substantially higher than that which humans can reasonably be anticipated to be exposed." The Working Group also concluded that, because sufficient data did not exist for determining a no observable effect level for EDB via oral, inhalation or dermal routes of exposures, acceptable levels of exposure could not be calculated for persons exposed by any of these routes following the pesticidal uses of EDB.

Based on the above evidence, the Agency adopted the following position in the PD-1:

> "On the basis of scientific studies and information summarized in the Position Document [(1)], the Agency has concluded that the risk index for reproductive effects has been exceeded by all registrations and applications for registration of pesticide products containing EDB and that a rebuttable presumption against new or continued registration of such products has therefore arisen."

Four rebuttals (Rebuttal nos. 3C, 48, 64, and 79) were submitted in response to the reproductive RPAR. The Agency has divided these into two broad groups: those which addressed uncertainties in extrapolating to man from the positive animal laboratory studies; and those studies which investigated the health of workers occupationally exposed to EDB.

a. Response to Rebuttals of Extrapolating from Animal Reproductive Disorder to Humans

No rebuttals seriously questioned the validity of the animal reproductive studies evaluated in the PD-1. However, all respondents noted the reversibility of the effects at all but the highest doses in hens and the general reversibility of effects in bulls following cessation of dosing. Respondents argued the effects produced in hens are probably specific to the hens and that the bull is specifically sensitive to EDB.

Generally, the rebuttals disputed the significance which the Agency placed on the animal studies in the PD-1. More specifically, the rebuttals argued that the reproductive disorders observed in bulls orally administered EDB cannot be used to determine a safe level of human exposure to inhaled EDB. The basis for this argument was that the bull is unusually sensitive to EDB. In addition, the rebuttals contended that it is inappropriate to determine a margin of safety by comparing levels to which humans are exposed via inhalation with the amount of EDB to which bulls were exposed orally.

The Agency concludes these rebuttals are not valid and do not change the Agency's position. In the absence of adequate human data, the Agency's normal policy is to use data from the most sensitive species which in this case is the bull. This procedure is dictated by regulatory prudence; in the absence of adequate human data it is reasonable to assume that man is at least as sensitive as the most sensitive species for which data are available. The question of assuming that all EDB inhaled is retained is basically similar to the question of the most sensitive species: in the absence of adequate data it is prudent to assume that the worst case applies (e.g., all inhaled EDB is retained). Thus, the Agency concludes that it is in the interest of public health to use the results from the reproductive studies on bulls to evaluate the reproductive risks to humans. In further support of this assumption, the

Agency has recently completed an inhalation study on rats (discussed later in this section) which demonstrates that this exposure route also causes deleterious effects upon the reproductive organs.

b. Response to Rebuttals Addressing Human Studies

In response to the reproductive RPAR in the PD-1, two epidemiology studies were submitted (Rebuttal no. 48). At the same time the Agency conducted its own study (Griffith, et al, 1978).

The first study submitted in rebuttal was a retrospective study of inferred fertility of married men occupationally exposed to EDB (Wong, 1977). Basic marital reproductive histories were collected from five groups of male workers - one group from each of four EDB manufacturing plants in the U.S. and a fifth group from a plant in Great Britain. For each of these groups, expected and observed births were compared for the families of workers exposed to EDB. Basically it was the conclusion from each of these "mini" studies that expected and observed human fertility were essentially the same and thus there was no evidence that EDB had an effect upon human fertility.

The Agency concludes that this study is of limited value in evaluating the human reproductive hazards of EDB. The Agency bases its rejection on numerous inherent weaknesses in the study and the general fact that negative fertility studies such as these are a very insensitive measure of the possible reproductive hazards of EDB. Two of the deficiencies in these studies, which were also noted by the author, included: 1) none of the U.S. groups had matching controls; and, 2) the data for the U.S. groups were compared to fertility data published by the National Center for Health Statistics which included non-married women, while the plant data did not, thus tending to artificially inflate the plant rates.

The second rebuttal study (Ter Haar, 1978) presented summary results of a sperm count survey of 59 employees of an EDB manufacturing plant at Magnolia, Arkansas. (This study was also referred to in rebuttal number 3C.). Workers were divided into two groups: those exposed to air levels of less than 0.5 ppm EDB and those exposed to levels between 0.5 - 5.0 ppm.

The Agency concludes that this study is of limited value in evaluating the possible reproductive hazards of EDB. In general, the Agency considers sperm count studies such as this one, which are negative, to be insensitive measuresof the possible human reproductive hazards of a substance. Reproduction is comprised of numerous facets, only one of which is the sperm count in males. Other parameters in males, including the number of abnormal sperm cells, motility of cells, and ultimately male fertility, can be affected. In addition, the potential effects on female reproduction must also be examined, even if a substance has been demonstrated to have no apparent effects on male reproduction. However, human sperm count studies which are postive and were conducted according to scientifically accepted protocols, do provide adequate evidence to demonstrate that a substance possesses risks of disorders to human reproduction. In addition to these general considerations, this particular study has specific technical flaws, including: 1) the failure to document or substantiate the finding of correlation between sperm count and exposure index; and 2) the failure to provide documentation on how workers were chosen for the study, the percentage of all exposed individuals included in the study, and the individual exposure estimates.

c. Recent Agency Sponsored Study

The Agency study (Griffith, et al., 1978) was undertaken to provide additional information on potential health effects of agricultural uses of EDB, with particular focus on reproductive effects. Semen samples were obtained from a total of forty-four individuals in four cohorts: (1) citrus fumigators at two locations in Florida; (2) rice fumigators in Texas; (3) citrus fumigators in Texas; and (4) a mixed group of carrot farmers and researchers in New Jersey. Semen samples were immediately analyzed for volume, sperm density, and motility. In addition, blood samples were drawn from all participants and tested for blood chemistries, testosterone levels, certain hormones and organochlorine residues (only for the Florida and Texas cohorts).

Air monitoring for EDB was conducted on a very limited basis. The number of data points were inadequate for use in standard statistical analyses to determine if EDB had a discernable effect on observed sperm measures. Initially, lifetime days of use and use-index (average pounds per day of use) were multiplied together and used as a surrogate measure of potential exposure to determine if an inverse relationship existed with the measured sperm counts. This surrogate was used because the Agency had very little data on the exposure to EDB of users. The Agency has since concluded however, that this surrogate exposure is an invalid measure of potential exposures to EDB. Recent monitoring studies demonstrate that citrus fumigators have significantly higher EDB exposures (on a yearly basis) than any other group of EDB users, and yet, this is one of the smallest volume uses of EDB. In contrast, soil fumigators use considerably more EDB, but are exposed to considerably lower levels of EDB than the citrus fumigators, because they soil-injected EDB outdoors using tractor-drawn chisels. Thus, this surrogate use index (days x lbs. applied per day) was a very inaccurate measure of the actual exposure to EDB for each cohort.

The Agency has summarized the sperm counts of the cohorts from this study in Table 5. In addition, in Table 6, the Agency has summarized results fromstudies conducted by McCloud which investigated sperm counts for males from"fertile marriages" and from "infertile marriages".

The Agency is reexamining the results from its study, but recognizes that the study will have very limited value to assessing the reproductive hazards of exposures to EDB. The study consisted of a very small number of individuals (a total of forty-four) and a much smaller numbers of individuals within each of the 4 cohorts. Standard statistical test results which take into account age and sex consist of such small sample sizes, would be of limited reliability.

d. Recent Agency Animal Study

The Agency has sponsored a study in which certain reproductive parameters were measured in rats exposed to EDB via inhalation (Short et al., 1978). While a variety of reproductive effects were noted in this study, the most noticable effect was atrophy of the prostate as illustrated in Table 7 below.

TABLE 5

SPERM COUNT DISTRIBUTIONS BY COHORT AND OCCUPATION

Cohort		Median Count	Frequency Distribution (%) of Counts (10^6ml) by Cohorts						%Counts
State	Occupation	(x 10^6/ml)	≤10	10.1-20	20.1-40	40.1-60	60.1-100	>100	≤20 (10^6/ml)
Florida	Citrus Fumigators (N=14)	53.5	14.3	7.1	14.3	21.4	7.1	35.7	21.4
Texas	Citrus Fumigators (N=17)	59.5	5.9	0	23.5	23.5	17.6	29.4	5.9
Texas	Rice Fumigators (N=8)	76.4	0	0	0	12.5	50.0	37.5	0
New Jersey	Carrot Farmers & Researchers (N=5)	123.0	0	0	0	0	20.0	80.0	0

TABLE 6

SPERM COUNT DISTRIBUTIONS FOR MALES FROM INFERTILE AND FERTILE MARRIAGES

		Median Count (10^6/ml)	Frequency Distribution (%) of Counts (10^{6}ml) by Cohorts						%Counts ≤ 20 (10^6/ml)
			≤ 10	10.1-20	20.1-40	40.1-60	60.1-100	>100	
Macleod 1977*	(N=9,000)	74	8.9	6.1	11.4	11.8	25.3	36.5	15.0
Macleod 1951**	(N=1,000)	90	(20-5%)+		12	12	27	44	5

*Males from infertile marriages
**Males from fertile marriages
+ Categories <10 and 10.1-20 combined

Table 7

Lesions in Reproductive Organs of Male Rats Exposed to EDB For 10 Weeks and Sacrificed at the End of Exposure

	EDB (ppm)*/			
Lesion	0	19	39	88
Testis				
Atrophy (Severe)	0/10[a]	0/10	0/10	6/6
Calcification	0/10	1/10	0/10	2/6
Epididymis				
Atrophy (Moderate to Severe)	0/10	0/9	0/10	6/6
Prostate				
Atrophy (Moderate to Severe)	0/10	0/10	10/10	6/6
Prostatitis	0/10	0/10	0/10	1/6
Seminal Vesicles				
Atrophy (Moderate to Severe)	0/10	0/10	0/10	6/6

---

* ppm in inspired air.

[a] Number of rats affected/number of rats inspected.

The results of this study suggest that the prostate is the most sensitive tissue. Thus, while the testis, epididymis, prostate and seminal vesicles are markedly atrophied in the presence of 88 ppm EDB, only the prostate is affected at 39 ppm. Based on this study, the NOEL for atrophy of the prostate is 19 ppm (146.11 mg/m^3) in the rat.

e. Conclusions on the Reproductive Effects RPAR

The Agency has examined the rebuttals submitted and other pertinent data and has concluded that the presumption of reproductive disorders as stated in the RPAR notice has not been rebutted because no respondent to that notice has sustained the affirmative burden of proof set forth in 40 CFR 162.11(a)(4). While there are no reliable human data available to help assess the human reproductive effects of EDB, the available animal data clearly indicate that EDB causes adverse reproductive effects in the bull, rat and hen. The inhalation NOEL for EDB in the rat is 19 ppm (146.11 mg/mg^3) based on atrophy of the prostate. Based on this NOEL and the exposure levels discussed in the next section, the Agency concludes that (as was originally stated in PD-1 with respect to the bull) there is not an ample margin of safety from adverse reproductive effects for humans exposed as a result of the current pesticidal use practices of EDB.

B. Human Exposure To EDB From Pesticidal Uses

Human exposures to EDB from pesticidal uses occur through three exposure routes: dietary, inhalation by evaporation of pesticides containing EDB, and dermal by contact with these pesticides.

1. Dietary Exposures

Residues of EDB may enter the human diet as a result of the following registered uses:

- o preplant soil fumigation of agricultural commodities and the possibility of groundwater, and, ultimately, drinking water contamination resulting from this use;
- o post-harvest fumigation of stored grains and grain products;
- o fumigation of grain mills, mill machinery, and handling equipment (including transportation equipment);
- o post-harvest fumigation of fruits, nuts or vegetables for quarantine purposes;
- o possibly through control of wax moths in beehives and associated equipment.

In the next five sections, dietary exposure levels resulting from each of these registered uses are examined. These data are taken from two major investigations on EDB residues occurring in the human diet: "Dietary Burden of Ethylene Dibromide Used as Soil, Grain, Grain Machinery, and Fruit Fumigant" (Holder, 1979), and "Final Dietary Exposure Analysis for Ethylene Dibromide Resulting from Residues in Fumigated Crops and Food Commodities" (Worthington, 1978).

a. Residues From Preplant Soil Fumigation

The Agency has examined the four known studies which investigated EDB residues in crops grown in EDB-fumigated soil. These include the following:

- o An unpublished series of reports to the Great Lakes Chemical Corp. from Litton Bionetics, Inc. (Rebuttal No. 3C);
- o An unpublished report from the Ministry of Agriculture and Forestry of Japan (Kenichi, 1978);
- o Data compiled by the Food and Drug Administration, DHEW, from their Compliance Program for DBCP and EDB;
- o A report by the California Department of Food and Agriculture (CDFA) analyzed 29 samples of nine crops grown in EDB-fumigated soils in California, with a stated level of detection of 1 part per billion (Maddy, 1979a).

Taken collectively, these studies indicate that residues of EDB in crops grown in EDB-fumigated soils are, if they occur, below the level of instrument detection. However, the Agency cannot be certain that residues will not occur. Each of these studies has been carefully reviewed by Agency scientists and each was found to have some deficiencies which precluded the Agency from categorically accepting their findings. The studies from both Litton Bionetics and Japan's Ministry of Agriculture and Forestry used analytical procedures which were only sensitive to 0.01 ppm and involved application rates of EDB which were generally less than standard rates. The FDA study involved analysis of foods obtained from retail groceries with no knowledge that EDB was even applied to the soil in which these crops were grown. In addition the analytical method was only sensitive to 0.01 ppm. The CDFA study (Maddy, 1979a) is probably the most convincing of all the studies to date. The level of detection is stated to be 0.001 ppm. However, because the analytical method used was not validated by CDFA through mass spectrophotometry, these data must be considered as preliminary.

The fact, that residues of the chemically related pesticide DBCP (in the .001-.01 ppm range) have been found in crops treated by similar use patterns, augments the concern that residues of EDB may occur. Therefore, in view of these findings, the Agency assumes that treated crops can bear EDB residues up to the limit of detection, which the Agency considers to be 0.001 ppm.

Using the 0.001 ppm residue limit, the Agency has calculated the potential body burden which may result from soil fumigation uses (Table 8). The body burden is calculated in mg EDB/kg body weight/day, assuming a 1,500 g diet and a body weight of 60 kg. The 60 kg body weight value is considered to be the average for an individual from a family of four. The food factors (the average percentage of the human diet) listed are the values reported in the update of the Food Factor Tables (Schmitt, 1978). The percentages of crops currently treated are documented by L. Zygadlo (1978) and the USDA/State/EPA Assessment Report (1978). The values for the estimated percentage of crops treated with EDB, if all DBCP uses are cancelled, are based on the portion of DBCP uses for which EDB is an alternative pesticide. The calculated dietary burden (DB) per day per person is derived from the calculation:

$$\mathrm{DB(mg/kg/day)} = \mathrm{ppm\ Residue} \times \frac{\mathrm{\%\ of\ the\ Human\ Diet}}{100} \times \frac{\mathrm{kg\ Diet}}{\mathrm{kg\ Body\ Wt}} \times \frac{\mathrm{\%\ Crop\ Treated}}{100}$$

As indicated in Table 8, the estimated average daily intake of EDB from residues in crops at current use levels is 2.59×10^{-7} mg/kg per day. If it is assumed that 100% of the crops bear EDB residues, the estimated dietary burden (DB) is 4.1×10^{-6} mg/kg per day. This latter figure is appropriate if an individual eats 100% treated crops.

Site preparation for fruit tree planting, an additional registered preplant use of EDB, is not listed in Table 8. This is because no detectable residues have been found in the fruits, and also because the Agency believes that it is extremely unlikely that this fruit would contain residues, due to the high volatility of EDB coupled with the many years between EDB application and first fruit harvest.

b. Postharvest Fumigation of Stored Grains

Grains are usually treated post-harvest to prevent insect infestation. Liquid mixtures of organic solvents such as carbon tetrachloride (CT), ethylene dichloride (EDC), and/or carbon disulfide (CS_2) are commonly used for this purpose. EDB generally constitutes inthe range of 1% to 9% of the weight of the liquid mixture. A mixture of chemicals is used because EDB alone would not penetrate sufficiently to the bottom of the storage bin. CT is an effective

Table 8

Calculated dietary burden (DB) of EDB residues in the human diet resulting from the soil fumigation uses.[1]

Crop	Crop Tolerances of Inorganic Bromide from Soil Incorporation (ppm)	Maximum Expected Residue of EDB (ppm)	% of diet made up of Currently Treated Crops	Food Factor of diet	DB if all of Crop Consumed Bears Residue (mg/kg/day)	Estimated EDB at Current Use Level (mg/kg/day)
Asparagus	10	0.001	NEGL.	0.14	3.50×10^{-8}	0
Broccoli	75	0.001	9.5	0.10	2.50×10^{-8}	2.38×10^{-9}
Carrots	75	0.001	21.0	0.48	1.20×10^{-7}	2.52×10^{-8}
Cauliflower	10	0.001	3.2	0.07	1.75×10^{-8}	5.60×10^{-10}
Corn, sweet	50	0.001	NEGL.	1.43	3.58×10^{-7}	0
Cotton	25	0.001	0.2	0.15	3.75×10^{-8}	7.50×10^{-11}
Cucumbers	30	0.001	28.0	0.71	1.78×10^{-7}	4.97×10^{-8}
Eggplant	50	0.001	1.4	0.03	7.50×10^{-9}	1.05×10^{-10}
Lettuce	30	0.001	0.2	1.31	3.28×10^{-10}	6.55×10^{-10}
Lima Beans	5	0.001	45.0	0.19	4.75×10^{-8}	2.14×10^{-8}
Melons	75	0.001	11.0	2.00	5.00×10^{-7}	5.50×10^{-8}
Okra	50	0.001	71.0	0.07	1.75×10^{-8}	1.24×10^{-8}
Parsnips	75	0.001	NEGL.	0.03	7.5×10^{-9}	0
Peanuts	25	0.001	0.1	0.36	9.00×10^{-8}	9.00×10^{-11}
Peppers	30	0.001	NEGL.	0.12	3.00×10^{-8}	0
Pineapple	40	0.001	27.0	0.30	7.5×10^{-8}	2.03×10^{-8}
Potatoes	75	0.001	1.1	5.43	1.36×10^{-6}	1.49×10^{-8}
Squash	50	0.001	NEGL.	0.03	7.50×10^{-9}	0
Strawberries	5	0.001	4.4	0.18	4.50×10^{-8}	1.98×10^{-8}
Sweet Potatoes	50	0.001	5.4	0.40	1.00×10^{-7}	5.40×10^{-8}
Tomatoes	50	0.001	6.8	2.87	7.18 x 10-7	4.38 x 10-8
				Total	4.1×10^{-6}	2.59×10^{-7}

"carrier" and EDC is added to the mixture to create the proper vapor pressure. A typical example of a commodity fumigant is Dowfume EB-5, which contains CT, EDC, and EDB in 63:30:7 proportions.

The data available to the Agency demonstrating residues in EDB-treated grains are taken from a variety of published papers which report a wide range of EDB residue levels. This broad range results from numerous factors, including the type and condition of grain, construction variation in storage bins selected, EDB application methods and rates, aeration and sampling techniques, and other related factors. Table 9 summarizes the ranges reported in the available studies.

Table 9

EDB residues (ppm) Reported in Fumigated Grains *

Aeration Period (Weeks) after Fumigation

Grain	0	1	4	13
Wheat	12-1500	1-240	5-33	0.6-5.3
Corn	37-1565	21-61	2.5-581	0.3-3.5
Sorghum	<1-5.7	14-45	2.1-15	0.9-8.5
Barley		2.2-6.3	1.-2.2	0.9-1.9
Rye	20-32			
Oats		10 - 15 "several weeks after fumigation"		

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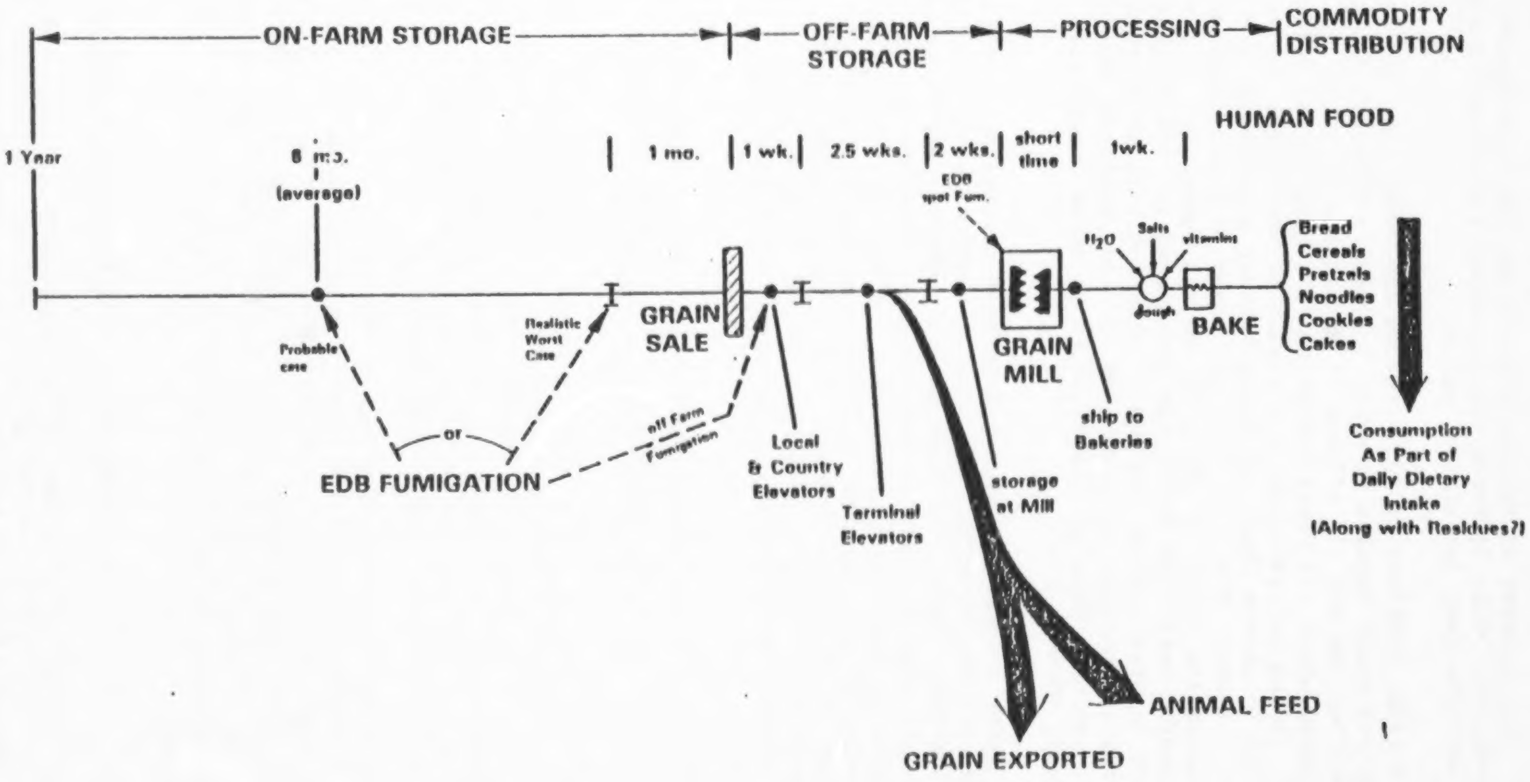
* (Worthington, 1978)

In spite of the wide variation in values reported, a consistent pattern of decline, which will be discussed later in the text, is apparent from the data presented in Table 9.

Of the grains for which EDB is registered as a fumigant, only wheat and rice make up appreciable portions of the human diet. Wheat forms by far the larger portion of the human diet than does rice: 10.36% for wheat and 0.55% for rice. Therefore, persistence of EDB in wheat is expected to have a much greater impact on the human diet (Holder, 1980). Accordingly, the Agency's analysis will focus on EDB residues in wheat, flour and bread.

It is important to note, however, that human dietary exposure can result from the use of EDB on other grains and rice. Corn oil, corn meal, corn cereals, other grains, and rice can contain residues of EDB as a result of the fumigation of stored corn, although most of the stored corn fumigated with EDB is used as livestock feed (DPRA, 1978). The Agency recognizes that these other uses could result in secondary contamination of the human diet through residues of EDB in meat, milk, rice and other products. However, the Agency has no data to support or dismiss this hypothesis, and therefore considers it to be a data

FIGURE I
TIME-LINE OF WHEAT AND WHEAT BY-PRODUCT DISTRIBUTION WITH EXPECTED TIMES FOR EDB FUMIGATION


ON-FARM STORAGE
OFF-FARM STORAGE
PROCESSING
COMMODITY DISTRIBUTION
HUMAN FOOD
1 Year
6 mo.
(average)
1 mo.
1 wk.
2.5 wks.
2 wks.
short time
1wk.
EDB spot Fum.
H₂O
Salts
vitamins
dough
Bread
Cereals
Pretzels
Noodles
Cookies
Cakes
Probable case
Realistic Worst Case
GRAIN SALE
or
EDB FUMIGATION
off Farm Fumigation
Local & Country Elevators
Terminal Elevators
storage at Mill
GRAIN MILL
ship to Bakeries
BAKE
Consumption As Part of Daily Dietary Intake (Along with Residues?)
ANIMAL FEED
GRAIN EXPORTED

gap. The presence of EDB residues, resulting from fumigation of these other commodities, would increase the estimated EDB dietary burden for its general use as a fumigant for stored grains.

Because residues of EDB entering the human diet from its use as a fumigant of stored wheat appears to dwarf its use as fumigant for all other grains, the Agency has focused its efforts on estimating the quantity of EDB contained in fumigated wheat and wheat products. The quantity of EDB in wheat, flour and bread varies considerably as a result of variations in the amount of EDB applied to stored wheat, duration between application and final use of product, type of storage facility used, and numerous other considerations. In order to determine the amount of EDB entering the human diet as a result of these registered uses, the Agency has considered all the available data on residues of EDB in wheat, flour and bread, obtained additional residue levels on these commodities through in-house studies, and developed several mathematical models which estimate expected EDB residues in these commodities at various points in movement through commerce.

Figure I (Holder, 1980) illustrates the typical movement of a shipment of grain through commerce. The top line indicates the general areas through which grain moves. Below this line are the Agency's estimated average periods for which the grain is held at each locus in commerce; the occurrence of EDB fumigations which the Agency has determined will be applied during the grain's movement through commerce; and a chronological list of the commerce areas through which the grain moves. As indicated in Figure I, the principal methods of grain distribution are export, animal feed, U.S. mills where grain is made into flour, and U.S. bakeries where flour is further processed to various baked goods.

The fumigation schedules shown in Figure I were used by the Agency (Holder, 1980) to estimate the concentrations of EDB in wheat and wheat products at each major point in its movement through commerce.

In addition to these time estimates, the Agency (Holder, 1980) developed three mathematical models (using results from laboratory studies) of the loss of EDB residues from wheat, wheat flour, and baked goods following post-harvest application of EDB. Using the schedule shown in Figure I, the Agency (Holder, 1980) calculated the "probable" concentration of EDB in bread to be 0.07 ppb, from which the resulting dietary burden of 1.8×10^{-7} mg/kg/day was estimated.

This same procedure was used to develop a "realistic worst case" estimate of the concentration of EDB at each point in commerce, and the dietary burden which would result from these concentrations. Using the same residue loss curves (RLC), but assuming a maximum application rate of EDB of 7.2 lbs/1000 bushels (instead of an average of 5.1 lbs./1000 bushels) and minimum treatment to market intervals, the Agency estimated the residue levels of EDB in bread and baked goods to be 31 ppb and an associated dietary intake of 3.3×10^{-5} mg/kg/day.

c. Fumigation of Grain Milling Machinery

In addition to residues of EDB that occur in wheat and wheat products as a result of grain storage fumigation, residues in many wheat products also result from the use of EDB in spot application to flour mill machinery and as a general space fumigant in these mills. The Agency has evaluated the three known studies (Wit, 1969, 1977, 1978) which have investigated the contribution of flour mill and machinery fumigation to EDB residue levels in wheat flour and baked breads (Holder, 1980). These studies generally involved sampling for EDB concentrations in incoming wheat, processed flour, and bread baked from that flour. Each of these sets of samples was taken at various times after spot fumigation.

Because the EDB concentration in the incoming wheat varied greatly from one study to the next, it is difficult to draw parallel conclusions from these three studies. The first two studies demonstrated that incoming washed wheat contained EDB, and that the resulting flour absorbed EDB from the spot-fumigated equipment (Holder, 1980).

In the Agency's opinion (Holder, 1980) the third and most recent study had such high levels of EDB in the incoming wheat that it probably "overshadowed any pick-up of EDB residues from the milling machinery due to spot fumigation." However, this study did show an increase in EDB residues in flour and bread up to 3-4 hours after spot fumigation. Using a time-weighted average of the differences between input wheat and the flour derived from the wheat, the Agency estimates that an average of 3 ppb of EDB persists in bread as a result of spot fumigation (Worthington, 1978). In the absence of the quantity of wheat flour processed annually through mills where EDB-treatment was used, the Agency has assumed that all flour mills fumigate with EDB. Using the residue level of 3 ppb, the Agency (Holder, 1980) estimates the dietary burden from spot fumigation for all wheat by-products to be 0.76×10^{-5} mg/kg/day, assuming all wheat by-products are equally contaminated with EDB.

Combining the dietary burden (DB) obtained for spot fumigation with the DB estimates for EDB used on stored grain, the Agency projects that the total contribution to dietary burden from residues in wheat and flour ranges from 0.24×10^{-5} to 4.1×10^{-5} mg/kg/day for all wheat fumigations (Holder, 1980).

In addition to these derived dietary burdens for all EDB fumigations, the Agency (Holder, 1980) has summarized data on residues of EDB measured in breads made with wheat treated with EDB. A total of 57 samples from 5 independent studies yielded an average observed residue level of EDB in bread of 38 ppb with a corresponding dietary burden of 4.1×10^{-5} mg/kg/day.

The Agency has efforts underway to obtain additional data on residues as they actually occur in commerce. The Benefits and Field Studies Division of OPP, in cooperation with the USDA's Federal Grain Inspection Service, has analyzed flour samples obtained from several of the USDA's programs for distributing flour to domestic charity programs, including the School Lunch Program (Marshall, 1980). Preliminary results of these analyses for EDB (Bontoyan, 1980) confirmed EDB residues in all of the samples analyzed in the first phase of this study.

Because this DB is derived from actual measurements of EDB residues observed in bread, it includes EDB residues resulting from both spot fumigation of grain milling machinery and grain storage fumigation.

It is worth noting the markedly good agreement between the DB of 4.1×10^{-5} determined from actual bread samples and the projected maximum DB of 4.1×10^{-5} derived from the assumptions and calculations discussed above

(Holder, 1980). Thus, the Agency concludes that the total dietary burden resulting from EDB fumigation of wheat in storage and of flour machinery is best estimated from the data collected from actual bread samples, which is 4.1×10^{-5} mg/kg/day.

For an "average" 60 kg individual in the U.S., this dietary burden translates into 2.5 micrograms of EDB consumed per day from the fumigation uses of EDB on stored grains. As discussed above, only fumigated wheat and wheat by-products were considered. The estimated dietary burden may slightly underestimate the actual DB resulting from the commercial use of EDB to fumigate stored grains. Considering the evidence currently available to the Agency, 4.1×10^{-5} mg/kg/day is the Agency's best estimate of the dietary burden resulting from all EDB fumigation.

d. Quarantine Fumigations

Several agricultural fruit and vegetable commodities are regulated by federal and interstate quarantines. These regulations were enacted to protect the importing state from the introduction of new insect or disease pests. U.S. quarantine treatments are legally mandated by authority of the Plant Quarantine Act of 1912 as amended (7 U.S.C. 151-167) and the Federal Plant Pest Act (7 U.S.C. 150aa, 150jj) through quarantine administrative instructions, and regulations. The U.S. Department of Agriculture's Animal and Plant Health Inspection Service (APHIS) is responsible for carrying out these mandates.

USDA regulations require treatment of imported commodities and of certain commodities transported out of quarantined regions (Table 10).

Table 10

U.S. Quarantine Requirements for EDB Treatment

Regulation	Commodities	Exporting Countries
7 CFR 318.13-45	bitter melons, bananas, litchi nuts, cucumbers, papayas, pineapples, cayenne, string beans, zucchini squash	Hawaii
7 CFR 318.58-3d	mangoes	Puerto Rico
7 CFR 319.56-2c	oranges, tangerines, grapefruits	Mexico and certain Central American countries
7 CFR 319.56-2j	mangoes, plums	Mexico, Guatemala

As a consequence of the U.S. quarantine requirements, EDB is registered as a commodity fumigant for post-harvest control of insects infesting citrus, tropical fruits (including mangoes, papayas, litchi fruit and nuts, and guavas), pineapples, bananas, cherries, plums, peppers, cucumbers, string beans, and zucchini squash. For many of these commodities, EDB is the only fumigant authorized by the USDA regulations. In addition, certain states also require fumigation of interstate transported commodities. In California, the State Administrative Code (section 3252) restricts importation of several citrus fruits from Puerto Rico and Florida. These commodities may only be received in the State after being fumigated at the point of origin in accordance with APHIS regulations.

EDB treatments are carried out in fumigation chambers as specified in Quarantine 13 (7 CFR 318.13), Quarantine 58 (7 CFR 318.58), and Quarantine 56 (7 CFR 319.56). Quarantine specifications call for the use of technical grade EDB of at least 97% purity, which is typically introduced into the fumigation chamber in the liquid state onto a home-variety electric frying pan for volatilization. This is the method used in Florida. An alternate method, used in Texas, involves the dripping of liquid EDB in front of a high speed fan. Because of the high density of EDB gas (more than six times heavier than air), forced circulation within the chamber is also required for volatilized EDB. The exposure period for both methods is two hours from the time all the required EDB has entered the chamber.

Over 99% of the 83,500 pounds of EDB used in 1977 for quarantine purposes was applied on citrus and tropical fruits (EPA, 1979). The remaining amount of EDB, less than 850 pounds, was used on an estimated 750,000 pounds of miscellaneous fruits and vegetables which constitute only miniscule percentages of the total U.S. production of each of these commodities (Zygadlo, 1978). The Agency recognizes that some EDB food residue exposure can occur from these minor uses. However, the national dietary burden which results from these minor uses is negligible and insignificant in comparison with that expected from EDB fumigation of citrus and tropical fruits (Table 13). Thus, these minor uses are not discussed further, although a maximum dietary burden of 18.8×10^{-2} mg/kg/day (Holder, 1980) could be expected if 100% of these minor crops were fumigated with EDB or an individual ate 100% of EDB-treated food.

There are some monitoring studies available on the residues of EDB in various fruits and vegetables resulting from quarantine fumigation with EDB. The studies show that, while EDB penetrates these commodities more rapidly and completely than it does grains, it also dissipates more rapidly from them (Worthington, 1978).

These limited data were compiled by the Agency (Worthington, 1978) to estimate the average EDB residues occurring in citrus and tropical fruits one day after fumigation. The Agency (Worthington, 1978) estimated the average EDB residues occurring in citrus and tropical fruits one day after fumigation to be 8.0 ppm and 6.0 ppm, respectively. Using these data and a residue loss equation, derived from the longest half-life time of two days, residues at any time (t) can be calculated. See Table 12 for calculated results.

Subsequent to these estimates the Agency obtained data from the State of California (Maddy, 1979b) on residues of EDB found in citrus and tropical fruits collected in 1979 from wholesale produce markets in that state. These fruits had been fumigated "to comply with USDA quarantine directives prior to entry into California." The Agency (Worthington, 1979) has evaluated these data, and summarized them in Table 11.

Table 11

Measured EDB Residues in Fruits Obtained from California Wholesale Produce Markets

Fruit	Period after Fumigation (days)	Number of Samples Taken	Range of EDB Residues (ppm)	Average EDB Residue Level (ppm)
Papayas	3 to 16	24	0.13 to 1.24	0.69
Oranges	8 or 16	9	0.06 to 6.35	1.37

The Agency (Worthington, 1979) has analyzed these data to determine if they support its estimate that one day after fumigation the EDB levels in citrus and tropical fruits are 8.0 ppm and 6.0 ppm, respectively, and has concluded that they do support these estimates. By taking the observed residue levels and the duration of these levels after fumigation, the Agency (Worthington, 1979) has extrapolated to one day after fumigation using dissipation equations. These results generally cluster around the EDB concentrations one day after fumigation as previously estimated (Worthington, 1978).

In order to calculate the most likely residue levels occurring in these commodities at the retail market, the Agency (Panetta, 1979) has obtained specific estimates of both the minimum and the average treatment-to-market intervals.

These time intervals and the initial residue levels were put into the residue loss equation discussed above to obtain estimates of residue levels in citrus and tropical fruit at the retail market (Table 12).

Table 12

Estimated EDB Food Residues Resulting From Required Quarantine Fumigation

Commodity	Estimated Initial Residue Level (ppm)	Estimated Market Residue Levels (ppm)	
		Maximum a/	Average b/
Citrus	8	1.42	0.425
Tropical Fruits	6	0.76	0.32

a/ Maximum residue levels assume a minimum treatment-to-market interval of 6 days for citrus and 7 days for tropical fruits. b/average residue levels assume 7 and 9.5 days, respectively (Holder, 1980).

The last two steps in calculating the DB for the U.S. population resulting from EDB fumigation of citrus and tropical fruits are to multiply the estimated residue levels from Table 12 by the percent crop treated, and multiply this product by the food factor (i.e., % of human diet which the commodity represents). The percent crop treated and consumed in the U.S. was first estimated to be 1.7% for citrus and 72% for tropical fruits (Zygadlo, 1978).

The estimate of the percent of crop treated for citrus was amended (Luttner, 1980) to 2.6% because the original estimate did not include citrus which is fumigated and imported to the U.S. The estimates of the food factors are 3.8% and 0.03% respectively for citrus and tropical fruits.

Accordingly, the following DB estimates have been calculated:

	Maximum DB (mg/kg/day)	Average DB (mg/kg/day)
Citrus	3.5×10^{-5}	1.05×10^{-5}
Tropical Fruits	0.41×10^{-5}	0.17×10^{-5}

e. Control of Wax Moths in Beehives and Associated Equipment

There are two Federally registered products containing EDB for controlling the wax moth (*Galleria mellonella*) in stored honeycombs. [The label of one product states that it is to be used on "...empty combs and empty hives" (Reg. No. 10092-1), while the other label gives directions for use, "When bee combs and/or hives are stored for the winter..." (Reg. No. 5785-46)]. No tolerances have been established for either organic EDB or the inorganic bromide ion residues for the use of EDB on honeycombs, because both registrations were considered nonfood uses. Although these labels do not specifically prohibit the use of EDB on honey or comb wax, it is not normal practice among beekeepers to do so. There are no known data on the potential for indirect EDB contamination through translocation to edible honey or beeswax as a result of fumigating stored comb-bearing frames or comb foundations. The Agency believes that no residues in honey are likely to result. Consequently, this registered use is not expected to contribute to the dietary burden of EDB.

f. Other Registered Uses of EDB

The remaining registered uses of EDB involve non-food uses and are not included in the dietary burden estimates. These uses include vault fumigation of stored clothing, structural termite control, control of bark beetles in coniferous trees, quarantine treatment of regulated articles for Japanese Beetle (including soil, plants with roots, and grass sod), and parasitic nematode control (including nursery plots, greenhouses, and potting soil).

g. Summary of EDB Dietary Exposures Resulting from Registered Use Practice

Table 13 is a summary of the daily dietary burden resulting from each of the food uses of EDB. This table shows the dietary burden at current use levels to be 1.21×10^{-4} mg/kg/day and 6.31×10^{-3} mg/kg/day if 100% of the crops on which EDB is used were treated. Included in this table are the relevant input data used to develop the dietary burden at current use levels. These include the average treatment-to-market interval, estimated EDB residue level at the time of entry into the human diet, the percent of total human diet made up by the given commodity, and the current percent of the commodity which is treated with EDB. As shown in this table, fumigation of stored grains and post-harvest fumigation constitute over 90% of the dietary burden which results from registered EDB use practices. The table does not include soil fumigation, where no residues have been found.

Table 13

Total Dietary burden (DB) of EDB residues in the human diet resulting from all commodity fumigation uses*

	Commodity	Average Treatment to Market Time (days)	Est. Residues at Time of Entry into the Human Dietary (ppb)	Food Factor % (of diet)	Commodity Currently Treated %	DB if all of Commod. is Treated (mg/kg/d)	DB at Current Use Levels (mg/kg/d)
1.	All Grain Products (Bulk Fumigation)	218	122	13.8	2.5	4.0×10^{-3}	10.1×10^{-5}
2.	Grain products (Spot fumigation)	1.0	0.003	10.1	100	0.76×10^{-5}	0.76×10^{-5}
3.	Tropical Fruits	9.5	320	0.03	up to 72	0.42×10^{-5}	0.17×10^{-5}
4.	Citrus	9.5	425	3.81	2.6	4.1×10^{-4}	1.05×10^{-5}
5.	Cherries	5	3000	0.10	NEGL.	7.50×10^{-5}	0
6.	Plums	5	3000	0.13	NEGL.	9.75×10^{-5}	0
7.	Peppers	5	3000	0.12	NEGL.	9.00×10^{-5}	0
8.	Cucurbits	5	500	2.78	NEGL.	3.48×10^{-4}	0
9.	Bananas	5	1000	1.42	NEGL.	3.55×10^{-4}	0
10.	String Beans	5	3000	0.98	NEGL.	7.35×10^{-4}	0
11.	Pineapple	5	2500	0.30	NEGL.	1.88 x 10-4	0
			Totals			6.31 x 10-3	1.21 x 10-4

*Holder, 1980

2. Inhalation and Dermal Exposures

All registered pesticidal uses of EDB may result in inhalation exposure. Applicators may be exposed during transfer, mixing, loading and actual application operations, calibration and repair of equipment, and reentry into fumigated structures or fields. Other workers not involved in the actual application of EDB may be exposed, including those working at or near grain storage sites and mills which have been fumigated, citrus quarantine fumigation stations, apiaries where fumigation has been used to control wax moths in beehives, and fields fumigated with EDB. The general public is not likely to experience significant inhalation exposure, although some exposure may occur in areas near quarantine fumigation stations, bark beetle control operations, and structures which have been fumigated for termite control. The major use patterns (for which quantitative exposure data are available) involving EDB inhalation exposure and risk estimates for specific populations at risk are presented in the following discussion. They are: a. preplant soil fumigation, b. citrus fumigation, and c. grain mill fumigation.

a. Exposure from Preplant Soil Fumigation

Ethylene dibromide is applied as a liquid pre-plant soil fumigant from tractor-mounted tanks or cylinders, using chisel injection or plow-sole methods.

The injection chisels or plow soles normally remain in the earth as the tractor moves across the field, and are removed only when the applicator turns the tractor around at the end of each pass. A small quantity of EDB may be released above ground when the chisels or plow soles are removed.

When EDB is applied with chisels, a float, cultipacker or roller is dragged behind the chisels to seal the soil. When plow-sole applications are used, the chemical is metered in front of the plow on the soil surface and immediately covered with soil by the plow behind and to the side of the treated area. Less than 5% of EDB is applied using the plow-sole method. However, in the preparation of pineapple fields, EDB is soil injected under a plastic mulch which prevents rapid volatilization.

Tractor operators and other applicator personnel may be exposed through volatilization of EDB before and/or after the sealing of the soil. In addition, exposure may also result from the calibration, cleaning or repair of equipment, from equipment failure, and from transfer and loading operations.

EDB is generally applied by open system operations, in which the pesticide must be transferred from 30 or 55 gallon drums by hand, powered pumps or gravity flow devices into tanks mounted above the injection chisels. There is potential for applicator exposure by inhalation of vapors and skin contact with the liquid during these open system transfer operations.

There is also a closed system method of transfer, in which EDB is fed to the chisels or plow soles from cylinders prepackaged with valves and diptubes, or containing a convenient orifice for attachment of suction tubes. The Agency is currently studying (but has not yet determined) the effectiveness of closed system technology in reducing worker exposure for many chemicals, including EDB (Mittelman, 1980).

The time duration for transfer operations and application varies, but it is roughly 10 minutes (0.17 hrs) for each transfer operation and 1.75 hrs for each application operation (Mittelman, 1980).

The Agency has estimated the annual exposure duration for total soil fumigation operations by site. These estimates are presented in Table 14. The estimates assume that transfer operations occupy 10% of the total application time.

1) Inhalation Exposure

There are relatively few measurement data regarding applicator exposure to EDB. The only sources of information are reports by the California Department of Food and Agriculture (Maddy, 1979c), Dow Chemical's Industrial Hygiene Laboratory (Vaccaro, 1976), and the Great Lakes Chemical Corporation (White and McAllister, 1977). The Dow and Great Lakes studies were submitted as parts of the rebuttal responses of these two manufacturers (Rebuttal Nos. 78 and 3C). These studies have been analyzed by the Agency (Mittelman, 1980).

Column 1 of Table 14 identifies the soil fumigation operation or location for which EDB air concentration was measured. The only measurements listed are those in which individual activities were monitored, in order to properly assess worker exposure. Air samples were taken during application alone (with open and closed cab), during transfer operations, while respiratory equipment was in use, and at sites on the treated field during application and up to 48 hours afterward.

The average EDB concentration measured in air (milligrams of EDB per cubic meter of air) at each of the sampling sites is listed in column 2. The use of closed cab tractors and closed transfer systems apparently did not reduce exposure to applicators involved in these studies; however, closed system research is currently being carried out, and insufficient data exist at this time to evaluate the future impact of closed cabs and transfer systems on applicator exposure.

The range of concentrations measured in each location and the number of samples taken are listed in columns 3 and 4. The greatest range of concentrations was measured during application activity in an open cab tractor where the exposures ranged from 0.008 to 4.75 mg/m^3. No range is listed for closed system transfer operations because a single sample was taken.

2) Dermal Exposure

The CDFA study (Maddy, 1979c) included measurements of EDB levels in hand washings taken from tractor drivers. The five samples taken ranged from 0.52 to 30.90 ug, with an average of 8.38 ug. Actual dermal contact incurred during transfer of EDB was not measured; however, the Agency assumes that the actual dermal contact incurred during normal operations will be at the same or higher levels than those measured from the hand washing samples because some EDB is expected to have evaporated or penetrated the skin (Mittelman, 1980).

3) Combined Inhalation and Dermal Exposure

The Agency (Mittelman, 1980) has estimated total inhalation and dermal exposures for private (non-professional) persons who both apply and transfer

Table 14

Measured air concentration of EDB during specific soil fumigation practices (1)

Exposure Situations	Average concentration in air (mg/m3)	Range (mg/m3)	Number of samples
Application/Closed cab	1.66	0.26 - 3.29	(n=5)
Application/Closed cab charcoal filtered intake	1.27	0.61 - 2.61	(n=4)
Application/open cab	0.81	0.008 - 4.75	(n=21)
Transfer operation/open system	3.03	0.77 - 5.30	(n=2)
Transfer operation/closed system	5.60	-	(n=1)
Area samples at field level:			
(A) During application	0.17	0.008 - 0.96	
(B) 24 hrs post-application	0.02	0.0008 - 0.05	
(C) 48 hrs post- application	0.07	0.05 - 0.08	

(1) Mittelman, 1980

EDB during soil fumigation. These estimates, contained in Table 16, assume a constant respiratory rate of 1.2 m^3/hr for light physical activity (No heavy activity breathing rates were used), a constant ambient air concentration (average of monitored values), and a range of exposure duration (see Table 15). Exposure estimates have been made for each use site (columns 1 and 2).

The total respiratory intake of EDB (milligrams per year) is presented in column 3 as the sum of exposures resulting from transfer and application operations. It is assumed that the applicator performs the transfer operation himself; 100% retention of inhaled EDB is also assumed. Total respiratory intake has been calculated in the following way, using data given for peaches as an example:

Inhalation Rate x (Transfer Exposure + Applicator Exposure) = Total Exposure
For peaches: 1.2 m^3/hr [(0.06 hrs. x 3.03 mg/m^3) +
(0.54 hrs. x 0.81 mg/m^3)] = 0.7 mg.

Total estimated dermal exposures are presented in column 4. An average dermal exposure value of 4.53 micrograms per hour is assumed (Maddy, 1979a). This value is based on EDB levels in water from hand washings, and assumes that the hand contact is the largest source of dermal exposure. Therefore, the dermal exposure estimates given here probably underestimate actual total dermal exposures.

One hundred percent of the EDB remaining on the skin is expected to be absorbed, based on data for DBCP, a chemically similar compound (Mittelman, 1980). Total estimated dermal exposure has been calculated by multiplying average dermal exposure by the duration of exposure. The following example, for peaches, uses figures from Table 15.

Dermal x (Transfer + Application) = Total Exposure

4.53 ug/hr x (0.06 hrs. + 0.54 hrs.) = 0.003 mg

The total estimated annual exposure (milligrams per year) is listed according to use site in column 4. It is expressed as the sum of the inhalation and dermal exposures for each use site. Assuming a 70 kilogram applicator, the maximum estimated exposure to EDB is experienced by pineapple applicators and transfer-operators. The total estimated annual exposure for this use site ranges from 303.3 to 532.4 mg/yr.

Commercial (professional) applicators' exposures are unknown, but the Agency (Mittelman, 1980) estimates that the duration of exposure of the approximately 25 professional applicators nationwide is roughly four times as long as that of the estimated 13,200 potentially exposed private applicators, based on data received from Great Lakes Chemical Co. (1977).

The CDFA (Maddy, 1979c) and Dow (Rebuttal No. 78) studies reported airborne concentrations of EDB in the breathing zones of applicators while respirators were in use. Based on the data from these studies, the Agency (Mittelman, 1980) concluded that the use of respirators can effectively reduce inhalation exposure by a factor of 14 for half-face and 24 for full-face respirators, but the use of closed tractor cabs is not necessarily effective, based on current data that demonstrate higher exposures in closed cabs than in open cabs.

Table 15 Estimated annual duration of exposure to EDB to soil fumigation workers (1)

Site	Annual duration of exposure (hrs)$^{(2)}$ Transfer	Application	Estimated number of exposed applicators (private only)
Peaches	.06	0.54	670
Tobacco	1 - 2.5	9 - 22.5	10,800 maximum
Peanuts (FLA, ALA, GA)	1.2	10.4	35
Pineapples	24.5 - 43	220.5 - 387	45
Vegetables	1 - 5.2	9 - 46.8	414
Sweet potatoes	0.2 - 0.3	1.8 - 2.7	650
Irish potatoes	0.4 - 0.7	3.6 - 6.3	150
Cotton (CA)	10	90	25
Cotton (AR, GA, MS, NC)	2 - 6	18 - 54	410
Citrus (pre-plant)	2.5 - 3.2	22.5 - 28.8	1
Citrus (burrowing nematode containment program)	41.6	374.4 (aggregate duration of 52 man days)	unknown

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(1) Mittelman, 1980

(2) For purposes of estimating exposure, the Agency has assumed a uniform transfer duration of 10% of total exposure time. Exposure during transfer is less when drums are mounted on the application rig and pumping into a tank is not required. The extent of this practice is unknown.

Table 16 Total estimated annual exposure to EDB for private applicators/transfer operators during soil fumigation. (1/)

Use Site	Total respiratory Intake of EDB (mg/yr) Transfer	Application	Total	Total estimated dermal exposure (mg/yr)(2/)	Total exposure (mg/yr)
Peaches	0.2	0.5	0.7	0.003	0.7
Tobacco	3.6-9	8.7-21.8	12.3-30.8	0.05-0.125	12.4-20.9
Peanuts	4.3	10.1	14.4	0.058	14.5
Pineapples	88.2-154.8	213.9-375.4	302.1-530.3	1.2-2.2	303.3-532.4
Vegetables	3.6-18.7	8.7-45.4	12.3-64.1	0.05-0.26	12.4-64.4
Sweet Potatoes	0.7-1.1	1.7-2.6	2.4-3.7	0.01-0.015	2.4-3.7
Irish Potatoes	1.4-2.5	3.5-6.1	4.9-8.6	0.02-0.035	4.9-8.6
Cotton (CA)	36	87.3	123.3	0.5	123.8
Cotton (AR, GA, MS, NC)	7.2-21.6	17.5-52.4	24.7-74	0.1-0.3	24.8-74.3
Citrus (preplant)	9-11.5	21.8-27.9	30.8-39.4	0.125-0.16	30.9-39.6
Citrus (burrowing nematode containment program)	149.8	363.2	513	2.08	515.1 (aggregate exposure)

(1) EPA. Mittelman, 1980. Assumptions are discussed in the text.
(2) Based on average dermal exposure of 4.53 ug/hr (Maddy, 1979).

4) Summary of Preplant Soil Fumigation Data

The data indicate that exposure to EDB results from all soil fumigation operations. The highest applicator exposures occur during transfer or loading operations. Exposures also result from broken hoses or other delivery lines and practices such as lifting chisels out of the ground while turning at the end of a row or passage and knocking off caked soil or organic debris from the chisels (Mittelman, 1980).

Data are not sufficient to estimate annual exposure resulting from dermal contact with EDB during soil fumigation. However, the Agency has collected data and estimated that EDB levels on the hands of tractor drivers range from 0.003 mg/yr for peaches to 2.15 mg/yr for pineapple (Mittelman, 1980).

More data are needed about the use of closed tractor cabs and closed transfer systems before their effectiveness can be evaluated. The Agency has been receiving comments on current efforts to develop a closed transfer system. EPA encourages such efforts.

b. Exposure from Citrus Fumigation

Ethylene dibromide is used in quarantine fumigation programs administered by the Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA). Target pests include several species of fruit flies which may infest various fruits and vegetables exported from the U.S. or shipped from state to state.

Quarantine fumigation of citrus is carried out at commercial facilities in all major ports of entry in the U.S.. In Florida, the State Department of Agriculture conducts quarantine fumigation at its own facilities.

The Agency has obtained data on inhalation exposure to EDB associated with quarantine fumigation of grapefruit in Florida (Mittelman, 1980). Two large fumigation centers in Wahneta and Fort Pierce, which operate under a cooperative program between the USDA and the State of Florida, and a Tampa warehouse were selected for study by EPA to investigate worker exposure to EDB.

The fumigation centers consist of stations where whole truckloads of citrus are fumigated in large drive-in chambers. The Wahneta station has twelve chambers and the Ft. Pierce facility has sixteen. The individual fumigation chambers are designed to accomodate truck trailers loaded with approximately 1000 boxes of pre-packed citrus. After the chamber is loaded and closed, a predetermined amount of liquid EDB is dispensed into an electric evaporator to start the two-hour fumigation. After the fumigation has been completed, the EDB is exhausted from the chamber into the outside atmosphere, and the trailer is hooked up to the tractor rig for transportation to dockside warehouses; most frequently at the Port of Tampa.

Several groups of people may be exposed to EDB during fumigation operations: fumigation center employees; truck drivers, when they enter the chamber to hook up the tractor-trailer rig, and later when they open the trailer doors to unload fruit at the warehouses; warehouse and dock workers, who unload fruit from the trucks, sort and stack the fumigated boxes in the warehouse, and move the boxes to ships for loading. There is also some potential for exposure of people who live, work or drive in the vicinity of fumigation operations, from EDB exhaust in the atmosphere and the venting of EDB from departing trucks.

1) Data on Applicator Exposure

The Agency has assessed inhalation exposure data from a number of studies on fumigation station workers at Ft. Pierce and Wahneta, Florida and warehouse workers at Tampa, Florida (Mittelman, 1980). Estimates of the annual inhalation exposure to EDB for these occupationally exposed groups are presented in Table 17.

The Agency (Mittelman, 1980) calculated the average annual inhalation exposure to EDB in milligrams per kilogram per year, assuming a 70 kg worker, in the following manner:

Exposures

Wahneta-Indoor Operations

Avg. Concentraton of EDB	Breathing rate	Hrs./ day	Working Days/yr.

$$0.207\ mg/m^3 \times 1.8\ m^3hr \times 8.0 \times 112 - 70\ kg = 4.8\ mg/kg/day$$

These calculations assume a concentration of EDB that is based on the average of all survey samples taken at each site, a moderate breathing rate (assuming 50% of the work shift is spent in slack activity, and 50% in heavy activity) a 112-day season at the fumigation station, and a 155-day season at the citrus warehouse.

The figures in the table indicate that the workers inside the warehouse apparently experience the highest exposure to EDB. These exposure levels are estimated to be up to one hundred times the average yearly dose experienced by fumigation station workers.

Major fumigation treatment operations are also performed in Texas and Hawaii. However, these operations are slightly different from the method employed in facilities in Florida. In Texas, EDB is applied by dripping the compound into a high-speed blower rather than by evaporation. Of the 36 total facilities in the U.S., there are 25 commercial stations and a number of private operations in Texas. There are no known air sampling data available from these stations. In Hawaii, the fumigation of papayas, bananas, citrus, litchi nuts and cucumbers is performed by evaporating EDB from a heating pan. Treatment operations occur throughout the year. The fruit is hand-carried in field boxes into and out of the fumigation chambers. High potential for exposures therefore exist. The Agency estimates that a total of 12 APHIS and 6 State of Hawaii employees monitor and supervise the fumigation activities. Though measurements using detector tubes have failed to detect EDB levels in worker space, the limits of sensitivity of these methods are relatively high in the range of 1-100 ppm, as compared to .008 ppm in Florida measurements (Mittleman, 1980).

In addition to the personnel employed at fumigation stations and warehouses, other persons are potentially exposed to EDB through quarantine fumigation uses. At the Wahneta and Ft. Pierce stations and at the warehouses,

Table 17. Inhalation exposure of workers to EDB at citrus fumigation stations and at a citrus warehouse

Location	Workers	Concentration of EDB (mg/m^3) Ave. (7/)	Number of Samples	Breathing rate 5/	Hrs/day 1/	Days/yr 2/	Avg exposure to EDB (mg/kg/yr) 4/
Wahneta -	Indoor operators	0.207	14	$1.8m^3$/hr	8	112	4.8
Ft. Pierce -	Indoor operators	0.607	1	$1.8m^3$/hr	8	112	14
Wahneta -	Outdoor operators	0.406	19	$1.8m^3$/hr	8	112	9.4
Ft. Pierce -	Outdoor operators	0.280	2	$1.8m^3$/hr	8	112	6.5
Wahneta -	Truckers/Station Personnel	0.048[8]	3	$1.8m^3$/hr	8	112	1.1
Ft. Pierce -	Truckers/Station Personnel	0.092	1	$1.8m^3$/hr	8	112	2.1
Wahneta -	Truckers	1.93	2	$1.8m^3$.hr	0.08	112[6]	0.4
Tampa -	Forklift operators, Laborers (inside)	8.99	1	$1.8m^3$/hr	8	155[3]	287
Tampa -	Forklift operators, Laborers (outside)	2.36	3	$1.8m^3$/hr	8	155[3]	75.3
Tampa -	"Stickmen"	4.76	2	$1.8m^3$/hr	8	155[3]	151.8

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1. Hrs/day are very variable depending on work load during year. Average 8 hr. work day is assumed here.
2. Data from APHIS (1977)
3. Assuming 22 working days a month over the period of October 11 through May 14
4. Assuming a 70 kg worker
5. Assuming heavy activity (Spector, 1956).
6. Assuming trucker returns once each day
7. Avg. of 48 monitoring study samples
8. Including "non-detectable" samples at level of detection (0.008 $mg.m^3$).

there are private residences located a short distance from the station. This small non-occupational population may be exposed. Truck drivers transporting citrus to the Florida chambers are also potentially exposed for several hours while waiting at the fumigation station, and when entering the fumigation chambers for short periods of time (approximately 5 minutes) to couple and uncouple their vehicles. Very little data are available on the levels to which these populations are exposed.

2) Summary of Exposure Data for Citrus

The data indicate that significant exposures to EDB are encountered by workers in all phases of quarantine fumigation operations. The highest exposures apparently result from warehouse work. However, the limited data available from Florida fumigation centers indicate that high levels of EDB occur at these facilities. There are no data available on fumigation facilities in other states. It appears that there is high potential for exposure in Texas and Hawaii (Mittelman, 1980).

A number of other people are likely to be exposed to EDB from fumigation operations. These include truck drivers and the general population living or driving near fumigation facilities. Although those living in homes adjacent tofumigation stations are exposed to very low levels of EDB (.025 mg/m^3 to 0.852 mg/m^3) there may be significant numbers of people exposed (Mittleman, 1980).

c. Exposure from Grain Mill Fumigation

EDB is used as a "spot" fumigant in grain mills. This use is a consequence of regulations of the Food and Drug Administration and U.S. Dept. of Agriculture which specify maximum acceptable levels of insects or insect parts in processed foods. EDB is particularly effective in flour milling machinery and equipment. There are many ledges and obstructions where the product accumulates, and infestation tends to occur. Proper "spot" treatment of these critical areas prevents insect growth and reproduction. Typically, a formulation containing 70% EDB and 30% methyl bromide is used, although a mixture of 59% EDB, 32% carbon tetrachloride and 9% ethylene dichloride is also common.

Spot fumigations are performed on flour milling and cereal handling equipment after running the machinery until it is as empty as possible, leaving only small quantities of the product trapped in the equipment. The fumigant is typically applied by means of applicator gun injection into holes in the milling equipment designed specifically for this purpose. Spot fumigants are usually applied over a weekend when the mill is shut down and personnel are away. The fumigation period typically lasts about 24 hours, after which the mill is aerated prior to the return of the mill workers. Mill fumigations are repeated on a 3-4 week cycle in order to interrupt the 4-6 week life cycle of invading target pests.

In addition to spot fumigators who apply EDB, personnel involved in opening the mill and mill workers themselves are also potentially exposed to substantial quantities of EDB during start-up procedures. In some cases, the same mill personnel are involved in fumigation, aeration and start-up procedures.

1) Data on Grain Mill Fumigator Exposure

A report commissioned by the Millers' National Federation and prepared by Industrial Health Engineering Associates (IHEA, 1978) provides the only data available to the Agency on EDB exposures resulting from grain mill fumigation. IHEA measured exposure levels of EDB both inside and outside respirator face masks worn by selected applicators during fumigation operations at five different mills.

Based on the IHEA data, the Agency (Mittleman, 1980) has calculated a worst-case exposure for applicators of 50.8 to 59.3 mg/kg/yr. This exposure estimate assumes that the respirator is not worn tightly against the face or that it is removed during application, and that there is no rotation of applicators. Alternatively, with proper use of the respirator and no rotation of applicators, an inhalation exposure of 4.3-12.5 mg/kg/yr is estimated. The bases for calculating these figures are presented in Table 18.

2) Summary of Spot Fumigation Data

The IHEA study indicates that exposure to EDB can occur during and after spot fumigation. The highest levels of EDB were measured during the opening and start-up operations in grain mills. The data indicate that spot fumigators are potentially exposed and encounter significantly lower levels of EDB when respirators are properly worn.

Estimated exposures to EDB for workers associated with spot fumigation are presented in Tables 18 and 19. Workers involved in spot fumigation are usually also mill employees therefore, application, opening and start-up are included in the inhalation exposure estimate in Table 18. Table 19 presents the inhalation exposure estimate for those millworkers not involved in fumigation.

3) Conclusions

The Agency has reviewed and evaluated all of the available data on inhalation exposures to EDB. Uses of EDB for which data were available include soil fumigation, quarantine fumigation of citrus, and grain mill ("spot") fumigation. The populations at risk from these uses of EDB are listed in Table 20. The remaining registered uses of EDB are listed in Table 20 and include vault fumigation of stored clothing, control of bark beetles in coniferous trees, termite treatment, fumigation of beehive supers, and control of Japanese Beetles and parasitic nematodes. Exposure data were not available for these uses. Table 21 is a summary of the estimated average dose of EDB experienced by soil fumigation applicators, quarantine fumigators and spot fumigators. These estimates are derived from exposure data which was analyzed by the Agency (Mittelman, 1980).

C. Quantitative Assessment of Risk Data

1. Oncogenicity

The Agency's Interim Cancer Assessment Guidelines (41 FR 21402) state that when a chemical is judged to be a potential human carcinogen, the Agency will estimate its possible impact on the public health at current and anticipated levels of exposure. The Cancer Guidelines also recognize that the available

Table 18. INHALATION EXPOSURE OF SPOT FUMIGATION APPLICATORS TO EDB

Job Category (Spot fumigation applicator)	Activity 1/	Duration of activity (hrs) 2/	Average concentration of EDB in the breathing zone (mg/m^3) Range in parentheses 3/	Number of applications per year per applicator 4/	mg/yr inhalation exposure 5/	mg/kg/yr/inhalation exposure 6/
I a) Proper use of respirator b) Rotation of applicators	Spot fumigation	1.65	1.8 (level of detection 0.8 - 2.3 n=3)	1.6 - 4.7	299.1-878.7	4.3 - 12.5
	Fogging	1.2	4.6 (n=1)			
	Opening alone (aeration)	0.5	12.8 (1.9-26.9 n=6)			
	Opening + start up	1.8	39.9 (30.6-54.2 n=5)			
	Normal operation	6.2	3.8 (level of detection)			
II a) Improper use of respirator b) rotation of applicator	Spot fumigation	1.65	17.1 (n=1)	1.6 - 4.7	474.1-1392.8	6.8 - 19.9
	Fogging	1.2	34.2 (n=1)			
	Opening alone (aeration)	0.5	12.8 (1.9-26.9 n=6)			
	Opening + start up	1.8	39.9 (30.6-54.2 n=5)			
	Normal operation	6.2	3.8 (level of detection)			
III a) Improper use of respirator b) No Rotation of applicators	Spot fumigation	1.65	17.1 (n=1)	12-14	3556-4148.7	50.8-59.3
	Fogging	1.2	34.2 (n=1)			
	Opening alone (aeration)	0.5	12.8 (1.9-26.9 n=6)			
	Opening + start up	1.8	39.9 (30.6-54.2 n=5)			
	Normal operation	6.2	3.8 (level of detection)			

Footnotes for Table 18.

1/ Space fogging with organophosphates or bin fogging with methyl bromide may occur following spot fumigation with EDB. Should this be the case, additional exposure to EDB will occur due to volatilization of EDB from the machinery. The mill may be opened (aerated) several hours to a day prior to start up or may be opened and started up simultaneously (IHE, 1978). Normal operation involves the typical milling cycle on the first day of renewed operation.

2/ IHE, 1978. (average of five mills). Values for each fumigation cycle.

3/ IHE, 1978. Concentrations of EDB are assumed present at level of detection.

4/ Estimate based on 6-15 applicators/mills (Boyersmith, 1977) and 12-14 applications annually (DPRA, 1978). If two applicators work together and applicators are rotated, then each applicator performs 1.6 to 4.7 fumigation cycles annually:

$$\frac{\text{14 applications}}{\text{3 application teams}} = 4.7; \qquad \frac{\text{12 applications}}{\text{7.5 application teams}} = 1.6$$

5/ Assumption of 100% inhalation retention and 1.8 m^3/hr respiratory rate (Spector,1956). The same employees may or may not be involved in all five activities listed. It is assumed here that the spot fumigator is involved in spot fumigation, fogging, opening and start up, and normal operation. This is a conservative assumption made in the absence of any data categorizing actual use practices. Fogging is not always carried out in conjunction with spot fumigation, and aeration (opening) is sometimes performed several hours to a day prior to start up.

6/ Assuming a 70 kg worker.

Table 19. Inhalation exposure of mill workers

Job Category	Duration of activity (hrs)1/	Average concentration EDB in breathing zone (mg/m3)2/	Number of applications per year3/	mg/yr Inhalation exposure4/	mg/kg/yr Inhalation exposure5/
Mill worker	8	3.8 (based on level of detection in air)	12-14	656.6-766.1	9.4-10.9

1/ During first working day after fumigation.
2/ IHEA, 1978. Estimate based on level of detection in the IHE, 1978 study.
3/ DPRA, 1978.
4/ Assuming 100% retention of EDB and a respiratory rate for moderate activity of 1.8 m^3/hr (Spector, 1956).
5/ Assuming a 70 kg worker.

Table 20. Populations at Risk

Site		
Soil injection [1/]	a)	about 25 commercial applicators
	b)	up to 13,200 farmer applicators
Florida citrus fumigation	a)	22 State employees
	b)	9 Federal employees
	c)	12-30 laborers per warehouse
	d)	unknown number of truckers
	e)	3 fumigation stations
Texas citrus fumigation	a)	30 APHIS personnel
	b)	75 commercial personnel
	c)	unknown number of truckers
	d)	25 fumigation stations
Hawaii fruit fumigation	a)	13 APHIS employees
	b)	10 State personnel
	c)	unknown number of commercial personnel
	d)	15 fumigation stations
Grain storage [2/]	a)	200 commercial applicators
	b)	potentially 50,000 - 60,000 farmers
Spot treatment [3/]	a)	2400 - 6000 potentially exposed spot fumigation applicators
	b)	about 16,000 mill workers
Bark treatment		unknown
Termite treatment		unknown
Japanese Beetle control		unknown
Parasitic nematode control		unknown
Bee-hive supers[4/]		about 7000 beekeepers
Vault fumigation		unknown

1/ Mittleman, 1980.

2/ Mittleman, 1980.

3/ Estimate based on 6-15 applicators per mill (Boyersmith, 1977). Actual fumigation is performed on a rotational basis (2 per fumigation). Mill worker estimate from DPRA, 1978.

4 Mittleman, 1980.

Table 21 Summary table of inhalation exposure to EDB

1. Soil injection	Average dose in mg/kg/yr
Private Farmer/Applicator	1. 0.01 - 1.8[1]
2. Citrus Fumigation (Florida)	
a. Fumigation station: Corridor operators	2. a. 2.3 - 7.5
b. Fumigation station: Outdoor operators	b. 5.1 - 6.5
c. Truckers/Station personnel	c. 0.4 - 2.1
d. Warehouse: Indoor laborers	d. 287[2]
e. Warehouse: Outdoor laborers	e. 75.3
f. Warehouse: "Stickmen"	f. 151.8
3. Spot Treatment	
a. applicator	3. a. 4.3-59.3
b. mill worker	b. 9.4-10.9
4. Grain Storage Treatment	4. No Data
5. Bark Treatment	5. No Data
6. Bee-Hive Supers	6. No Data
7. Termite Treatment	7. No Data
8. Vault Fumigation	8. No Data
9. Japanese Beetle Control	9. No Data
10. Parasitic Nematode Control	10. No Data

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[1] This excludes pineapple use, for which the private applicator/loader dose may be as high as 7.6 mg/kg/yr. Specialized cultural practices may lower this dose significantly.

[2] Based on a single personal sample of 8.99 mg/m^3. Area samples, however, support the presence of such high concentrations (Mittelman, 1980).

techniques for assessing the magnitude of cancer risk to humans based on animal data are at best very crude. This is due to several causes, e.g., uncertainties in the extrapolation of dose-response data to very low dose levels and differences in levels of susceptibility in animals and humans. Accordingly, these risk estimates are neither scientific certainties nor absolute upper limits on the risk of cancer from exposure to EDB. The estimates should therefore be viewed as an index of potential health hazard that incorporates both the degree of carcinogenicity of the compound in animals and the measured, and/or estimated human exposures.

The CAG has estimated an individual's lifetime probability of EDB-induced cancers resulting from:

- ingestion of EDB in treated food commodities (CAG, 1980a)
- occupational inhalation exposure to EDB (CAG, 1980c)

Risk estimates for EDB dietary and occupational exposure were calculated using a standard one-hit no-threshold model based on the following general equations;

$$\text{Risk} = 1-e^{-Bx}\text{; and}$$
$$B = (1/y)\ \ln\ [1/(1-P)];$$

where: B = slope coefficient of the one-hit model
$P = (Pt-Pc)/(1-Pc)$
Pc= incidence of tumors in control animals
Pt= incidence of tumors in test animals
y = test animal exposure (ppm)
x = potential human exposure (ppm)

As will be discussed below, the Agency adjusted the slope coefficient (B) of this equation to account for differences between exposure routes of the laboratory study used, which was gavage, and the estimates of amounts of EDB inhaled and consumed via dietary contamination.

a. Dietary Exposure

The CAG estimated cancer risks associated with EDB residues in the diet using the Agency's dietary exposure analysis (Holder, 1980), and the results of a long-term bioassay study of Osborne Mendel rats and B6C3F1 mice, completed by the National Cancer Institute (Hazelton Laboratories, 1975). EDB was administered by intubation for two years, causing a significant increase in the incidence of gastric tumors. The Agency used this study to derive a risk equation for lifetime exposure, measured in mg/kg/day. This equation incorporated both time and dosage in estimating tumor response rate.

The Agency recognized that use of the NCI study could be criticized because the dose delivered by gavage might not be comparable to dosing by ingestion or inhalation. As a result, the Agency adjusted the NCI tumor incidence results to account for the potential differences in tumor incidence which may occur because of differences in exposure routes. Through a comparison of the adjusted NCI figures with the results of a dietary DBCP study administered to CR albino rats (Hazelton Laboratories, 1977), the CAG derived an approximate estimate of the relative carcinogenic effectiveness of the two methods of administration and adjusted for EDB potency via the dietary route. To obtain an estimate of EDB potency via dietary ingestion, the intubation value for EDB (B = 31.73) was multiplied by the ratio of dietary to intubation parameters found for DBCP, which gave: B = 31.73 x 0.5897 = 18.71. This adjustment is based on the assumption that the ratio of oral to intubation tumor incidence is the same for EDB as for DBCP because the two pesticides are similar in both their chemical structure and their carcinogenic potential (CAG, 1979).

Estimates of cancer risks associated with EDB residues in the diet are illustrated in Table 22 which is based on "probable EDB dietary burden." The estimated lifetime probability of EDB-induced cancer is 2.6 x 10^{-6} for grain fumigation of wheat, 5.60 x 10^{-5} for soil fumigation, 2.7 x 10^{-5} for quarantine fumigation of tropical fruit, 5.1 x 10^{-5} for spot fumigation of wheat, and 1.8 x 10^{-4} for quarantine fumigation of citrus fruit. The total lifetime probability of EDB-induced cancer is 3.2 x 10^{-4}.

Table 23, based on "realistic worst case EDB dietary burden," shows the lifetime probability of EDB-induced cancer from general use categories. The probabilities range from a low of 6.6 x 10^{-5} for soil fumigation and quarantine fumigation of tropical fruit to a high of 5.7 x 10^{-4} for quarantine fumigation of citrus fruit. Other probability values are 1.2 x 10^{-4} for spot fumigation of wheat and 5.3 x 10^{-4} for grain fumigation of wheat. In summary, Table 23 shows that the average lifetime probability of EDB-induced cancer from residues in an average diet is 1.5 x 10^{-3}.

Table 24 lists the risks of EDB-induced cancer from ingestion of crops grown in soil fumigated with EDB. The range extends from 0 probability to 8.8 x 10^{-7} for melons. The total risk is 4.2 x 10^{-6}. This risk assumes that crops bear residues up to 0.001 ppm.

b. Non-Dietary Exposure

Risk estimates for those groups occupationally exposed to EDB are based on the Agency's "Non-Dietary Exposure Analysis for EDB Uses" (Mittelman, 1980), and the results of a recent study designed to assess the carcinogenicity of inhaled EDB to Sprague-Dawley rats. The Agency (CAG, 1980c) derived a direct estimate of the carcinogenic potency of inhaled EDB using a statistical model, adjusted for the lack of full lifetime exposures, and applied it to the results of this study. The Agecny used the significant tumor types found in the female rat to estimate the lifetime probability of a cancer case in humans. This lifetime probability was estimated to be:

$$P = 1 - e^{-1.7X}$$

where:

X = estimated human lifetime average exposure

The CAG applied the above statistical model to the Agency's estimates of occupational inhalation exposure and numbers of people exposed. Table 25 presents the risks resulting from occupational exposures to EDB vapors. The exposure level presented in the second column of the table was obtained by the calculation d = (40X)/(71.3 x 365), where X is the exposure level in terms of mg/kg/year. It is assumed that of a theoretical 71.3 year lifespan, 40 years are spent in the occupation. Although the estimates of the lifetime probability of cancer presented in the table are in the high range, of particular concern are the risks to citrus warehouse workers whose estimated lifetime risks of EDB induced cancer can be as high as 4 chances in 10 of (CAG, 1980c).

The Agency (Mittelman, 1980) has estimated that from 50,000 to 60,000 workers in grain storage facilities are exposed to EDB. The risk to these workers cannot be estimated because the level of exposure is not known. Risk estimates for the lower volume uses of EDB were not calculated, because of a lack of exposure estimates.

2. Mutagenicity

As discussed earlier in this chapter, the presumption of mutagenic risk to humans from exposure to EDB has not been rebutted. The Agency concludes the human exposure to EDB also result in risk of mutagenic damage. The Agency is also developing Mutagenicity Risk Assessment Guidelines that will be utilized by the Agency for various chemicals as needed.

3. Reproductive Effects

As discussed earlier in this chapter, the presumption of risk of reproductive effects to humans from exposure to EDB has not been rebutted. No quantitative reproductive risk estimates will be developed, because the available health studies were determined to be inadequate to support a quantitative assessment.

4. Summary and Conclusions

The Agency has applied results from laboratory studies in estimating the individual lifetime probability of EDB-induced cancers from both dietary and occupational exposures. The dietary risk estimates from all registered uses range from 3.2×10^{-4} for the "probable dietary burden", to 1.5×10^{-3} for the "realistic worst case dietary burden", with quarantine fumigation contributing 2.1×10^{-4} and 6.4×10^{-4} to the respective ranges. The occupational risks of EDB-induced cancers resulting from inhalation of EDB vapor range from 1.8×10^{-5} to as high as 4 chances in 10 for citrus warehouse laborers.

Although the Agency concludes that there is a risk that mutagenic damage and reproductive disorders could result from exposures to EDB, the Agency has not quantified these risks.

D. Risks of the Alternative Pesticides to EDB

Table 26 summarizes all of the known risks for major alternative chemicals to EDB. These seventeen pesticides could be substituted for EDB depending upon the use that was cancelled. The regulatory status for each is also given. Four of the substitute chemicals are either on the RPAR list or candidates for RPAR, and most are restricted to use by certified applicators. In Chapter V, the risks of each substitute are compared to EDB on a use-by-use basis.

TABLE 22

ESTIMATES OF THE CANCER RISK DUE TO "PROBABLE EDB DIETARY BURDEN"

Source	EDB dietary burden (mg/kg/day)	Lifetime probability of EDB-induced cancer
Soil Fumigation	2.6×10^{-7}	5.6×10^{-5}
Grain Fumigation (wheat)	1.8×10^{-7} (4.1×10^{-5})	2.6×10^{-6} (6.28×10^{-4})
Spot Fumigation (wheat)	3.2×10^{-6}	5.1×10^{-5}
Quarantine Fumigation:		
Citrus	1.1×10^{-5}	1.8×10^{-4}
Tropical fruit	1.7×10^{-6}	2.7×10^{-5}
Total	1.6×10^{-5} (5.7×10^{-5})	3.2×10^{-4} (9.0×10^{-4})

The parenthesized value (4.1×10^{-5} mg/kg/day) is calculated from 57 samples of residue. Non-parenthetical values were derived from models using application rates. (Litton Bionetics, Inc., 1978).

TABLE 23

ESTIMATES OF CANCER RISK DUE TO "REALISTIC WORST CASE EDB DIETARY BURDEN"

Source	EDB dietary burden (mg/kg/day)	Lifetime probability of EDB-induced cancer
Soil Fumigation	4.1×10^{-6}	6.6×10^{-5}
Grain Fumigation (wheat)	3.3×10^{-5}	5.3×10^{-4}
Spot Fumigation (wheat)	7.6×10^{-6}	1.2×10^{-4}
Quarantine Fumigation:		
Citrus	3.5×10^{-5}	5.7×10^{-4}
Tropical fruit	4.1×10^{-6}	6.6×10^{-5}
Total	8.4×10^{-5}	1.5×10^{-3}

TABLE 24
UPPER BOUND CANCER RISKS DUE TO INGESTION OF CROPS GROWN IN SOIL FUMIGATED WITH EDB

Crop	Maximum expected residue ppb	Estimated dietary burden at current use level in mg/kg/day	Lifetime probability of EDB-induced cancer
Asparagus	1	0	0
Broccoli	1	2.4×10^{-9}	3.8×10^{-8}
Carrots	1	2.5×10^{-8}	4.0×10^{-7}
Cauliflower	1	5.6×10^{-10}	9.0×10^{-9}
Corn, sweet	1	0	0
Cotton	1	7.5×10^{-11}	1.2×10^{-9}
Cucumbers	1	5.0×10^{-8}	8.0×10^{-7}
Eggplant	1	1.1×10^{-10}	1.7×10^{-9}
Lettuce	1	6.6×10^{-10}	1.1×10^{-8}
Lima Beans	1	2.1×10^{-8}	3.4×10^{-7}
Melons	1	5.5×10^{-8}	8.8×10^{-7}
Okra	1	1.2×10^{-8}	2.0×10^{-7}
Parsnips	1	0	0
Peanuts	1	9.0×10^{-11}	1.4×10^{-9}
Peppers	1	0	0
Pineapples	1	2.0×10^{-8}	3.3×10^{-7}
Potatoes	1	1.5×10^{-8}	2.4×10^{-7}
Squash	1	0	0
Strawberries	1	2.0×10^{-9}	3.2×10^{-8}
Sweet Potatoes	1	5.4×10^{-9}	8.7×10^{-8}
Tomatoes	1	4.9×10^{-8}	7.8×10^{-7}
		2.6×10^{-7}	4.2×10^{-6}

Table 25
CANCER RISK DUE TO OCCUPATIONAL INHALATION OF EDB

Exposed group	Range of exposure (mg/kg/day)	Lifetime probability estimates	No. of workers exposed
Soil injection farmer applicator	$1.5 \times 10^{-5} - 2.8 \times 10^{-3}$	$1.8 \times 10^{-5} - 3.2 \times 10^{-3}$	13,200
Fruit fumigation(3)			
station corridor operator	$3.5 \times 10^{-3} - 1.2 \times 10^{-2}$	$4.1 \times 10^{-3} - 1.3 \times 10^{-2}$	11(1)
station outdoor operator	$7.8 \times 10^{-3} - 10.0 \times 10^{-3}$	$9.1 \times 10^{-3} - 1.2 \times 10^{-2}$	10
trucker/station personnel	$6.2 \times 10^{-4} - 3.2 \times 10^{-3}$	$7.2 \times 10^{-4} - 3.8 \times 10^{-3}$	10
Warehouse(3)			
Indoor laborer	0.4	0.4	4-10(2)
Outdoor laborer	0.1	0.1	4-10
Stickman	0.2	0.2	4-10
Spot fumigation			
Applicator	$6.6 \times 10^{-3} - 9.1 \times 10^{-2}$	$7.7 \times 10^{-3} - 0.10$	2400 - 6000
Millworker	$1.5 \times 10^{-2} - 1.7 \times 10^{-2}$	$1.7 \times 10^{-2} - 2.0 \times 10^{-2}$	16,000

(1) Assumed that 31 federal and state employees are evenly distributed.

(2) Per warehouse. Seasonal variation. Assumed that 12-30 laborers per warehouse are evenly distributed.(Mittelman, 1980)

(3) Figures are for Florida only. No data are available as to exposures in Texas or Hawaii.

Table 26 Human Hazards of Substitutes for EDB

(* - most likely alternative if all EDB uses were cancelled)

Chemical	Potential Hazards to Man	Regulatory Status
Aldicarb	Acutely Toxic	Some uses restricted Others under evaluation
*Aluminium Phosphide	Acutely Toxic Explosive	All uses are restricted
Carbofuran	Anticholinesterase Reproductive Effects Acutely Toxic Immuno-suppressant	Most uses restricted Others under evaluation
*Carbon Disulfide	Explosive (Tox Profile was not done- literature being assembled)	Most uses restricted
*Carbon Tetrachloride	Oncogenicity Mutagenicity Nephrotoxicity Hepatotoxicity	Notice of RPAR issued 10/15/80.
Chloropicrin	Lung Irritant Skin Irritant Acute Toxicity	Most uses restricted
Dasanit	Anticholinesterase	No action
D-D (contains 1,3 dichloropropene)	Oncogenicity Lung, liver & kidney damage Mutagenicity Eye & skin irritant	See Telone
*Ethylene Dichloride	Oncogenicity Mutagenicity	Accepted for pre-RPAR
Hydrogen cyanide	Acutely Toxic	All uses restricted

Human Hazards of EDB Substitute Chemicals - (cont'd)

Chemical	Potential Hazards to Man	Regulatory Status
*Methyl Bromide	CNS lesions Skin irritant Mutagenicity	Most uses restricted Accepted for Pre-RPAR review
Mocap	Anticholinesterase Acute toxicity	Some uses restricted Others under evaluation
Nemacur	Eye & skin irritant	Liquid formulations are restricted Granular formulations are proposed for restriction
Paradichloro benzene	Oncogenicity	Accepted for pre-RPAR
Silica aerogel	Eye Irritant	No Action
Telone (1,3 dichloropropene)	Oncogenicity Mutagenicity (*in vitro*)	Accepted for RPAR
Vorlex (contains 1,3 dichloropropene	Eye & skin irritant	See Telone

references: Federal Register, 1978
Federal Register, 1979a
Federal Register, 1979b
Mishra, L; 1978b

III. BENEFITS SUMMARY FOR ETHYLENE DIBROMIDE

A. Introduction

EDB is used for a variety of agriculturally related activities. It is produced in the U.S. by the Great Lakes Chemical Corporation and Dow Chemical Company, and its production and marketing data are confidential. However, it has been estimated that in recent years approximately 13 to 15 million pounds of EDB have been used annually as a pesticide active ingredient. Sites treated include: preplant soil fumigation of agricultural crops (tobacco, pineapple, citrus, peaches, peanuts, cotton and various vegetables); fumigation of stored beehive supers; termite control; fumigation of stored grain; spot fumigation of flour milling machinery; for Federal (APHIS) quarantine programs; and on felled logs for control of bark beetles.

Estimates of annual usage were made in 1978 by the USDA/State and EPA Cooperative Assessment Team. In 1979, DBCP, one of the major alternatives to EDB, was largely banned from the market. This most likely resulted in some increase in EDB usage for certain sites. Because it was not possible to determine the magnitude of these increases, the original 1978 estimates of annual usage were used as a base for most of the sites analyzed.

Benefits analyses for all sites except stored grain and flour mills were prepared jointly by economists of EPA and USDA (Abbreviated Benefits Analysis of Pesticidal Uses of Ethylene Dibromide, January, 1979). Analyses of flour mills and stored grain were performed under EPA contract by Development Planning and Research Associates, Inc., of Manhattan, Kansas.

The alternatives to EDB were chosen on the basis of cost, efficacy, and availability. Economic impacts of alternatives were estimated using partial budgeting. This methodology allowed measurement of the change in control costs and yield, if any, while holding all other inputs and their costs constant.

Cancellation of all current uses of EDB are expected to result in annual losses to users of approximately $60.0 million (Table 27). This represents losses due to both increased cost of treatment and decreased value of production for certain crops. The largest single impact would be noticed through the APHIS citrus quarantine program, where shippers and producers could suffer a net loss of $24 million, and where balance of payments deficits could increase by approximately $18 million, if the export market to Japan were lost.

In calculating these impacts, it was assumed that only currently registered pest control methods would be available at the time EDB cancellation becomes effective. Over 30% of the estimated impact of $60 million would occur in the APHIS quarantine program for which there are no known chemical alternatives to EDB. Extensive research conducted in recent years demonstrates that the use of gamma radiation can be an effective pest control method (Interdepartmental Committee on Radiation Preservation of Food, December 1978). A number of foreign countries and the U.S.A. have approved irradiation of certain food products for human consumption (Appendix II). Though irradiation of wheat, wheat flour and white potatoes has been approved in the U.S., the Food and Drug Administration, the Federal body responsible for these approvals, has not yet resolved a 1973 petition (FAP #3045) from USDA requesting approval of the use of gamma irradiation on papayas and citrus. Should this pest control method be approved and accepted by foreign export markets, the impacts of cancelling EDB may be reduced significantly.

B. Fumigation of Stored Grain

EDB is used in combination with ethylene dichloride and carbon tetrachloride for insect control in stored grain. A total estimated 630,000 pounds of EDB active ingredient are used annually in grain storage facilities: 409,000 pounds are applied on farms, while 221,000 pounds are used in commercially stored grain. Approximately 225 million bushels of stored grain, or about 2% of the grain produced in the country, are treated annually with fumigants containing EDB.

The most likely alternative to EDB-containing mixtures is the 80%/20% mixture of carbon tetrachloride and carbon disulfide at on-farm storage facilities, and aluminum phosphide at off-farm storage centers. Because on-farm and off-farm facilities vary greatly in air-tightness the substitutes also vary; the tighter the facility, the more likely it is that the substitute would be aluminum phosphide. When used as directed, both carbon tetrachloride/carbon disulfide and aluminum phosphide will be less costly than EDB. As a result, fumigation costs will actually decline if EDB becomes unavailable and is replaced with these alternatives. The Agency estimates a $500,000 to $2,260,000 annual savings from use of these EDB alternatives.

Another alternative treatment method which is effective against a broad spectrum of pests of stored grain is the use of a controlled atmosphere of carbon dioxide, nitrogen and combustion products of natural gas. These gases can be circulated through a sealed bin, reducing the oxygen in the bin atmosphere to a very low level and killing any pests. In all cases, bins must be sealed tightly, grain temperatures must exceed 70° F. and the exposure time must be at least four days. The commodities are not contaminated with any chemical residues. The performance of this treatment method is optimum in silos and other readily sealed sites, but use in flat bed storage is unlikely. In response to a petition for exemption from tolerance submitted by the USDA IR-4 minor use program, the Agency has proposed to grant this exemption (Federal Register, Vol. 45, No. 136, July 14, 1980, p. 47168). Commerical acceptance and use of this controlled atmosphere method could occur once the exemption from tolerance is made permanent; thus, another alternative for this use of EDB could become available. The Agency has no information regarding the costs of such a treatment system and would be interested in obtaining such information from any knowledgeable party.

C. Quarantine Fumigation of Citrus, Tropical Fruits and Misc. Fruits and Vegetables.

USDA's Animal and Plant Health Inspection Service (APHIS) requires the use of EDB in its quarantine program to destroy certain fruit flies before they become established in parts of the U.S. For the same reason, Japan also requires that all fresh grapefruit imported from the U.S. be treated with EDB. The target flies include the Mediterranean, Caribbean, West Indian, Oriental, Melon, Queensland, and the Cherry fruit fly. In 1977, approximately 83,500 pounds active ingredient of EDB were used to meet the requirements of APHIS and Japan.

There are currently no registered chemical alternatives to EDB for quarantine purposes. Vapor heat (112° F for 4-6 hours, followed by chilling) and cold storage (36° F for 10-22 days) can control these flies as effectively as EDB, however, its use often results in varying and considerable degrees of fruit damage.

Table 27. Annual Economic Impacts of Cancelling Ethylene Dibromide

Use sites	Active Ingredient Applied Thousand pounds	Extent of use (Units Treated)	Change in Cost of Treatment	Decrease in Value of Production	User Impacts	Market/ Consumer Impacts	Balance of Payment Impacts
			thousand dollars.1/				
Tobacco	2,100.0	77,600 acres	1,200.0	0	1,200.0	none	0
Pineapples	572.4	11,500 acres	281.5	1,218.5	1,500.0	minor	0
Citrus							
A. Preplant	20.0	100 acre	3.5	0	3.5	none	0
B. Burrowing nematode containment	252.0	500 acres	44.0	0	44.0	none	0
Peaches 2/	170.0	2,000 acres	20.3 to 118.2	0	20.3 to 118.2	none	0
Forestry 3/	20.0	68,000 acres	7.4 to -15.8	unquantifiable	7.4 to 15.8	none	0
Termites	20.0	12,400 structures	unknown	-	-	none	0
Grain Storage	630.0	125.7 to 392. 0 mil. bu.	-2,258.0 to -500.0	0	2,258.8 to -500.0	none	0
Flour Milling	465.0	391 mill	4,000.0 to 7,700.0	0	4,600.0 to 7,700.0	$0.016 to $.028 per capita	0
Quarantine (APHIS)	83.5	494.5 mil. lbs.	538.9	24,164.0	24,702.9 4/	price reduction for grapefruit; price increase for papayas & mangoes	18,384.0
Peanuts	4,197.4	257,390 acres	2,500.0	11,000.0	13,500.0	none	0
Cotton	721.8	55,600 acres	435.7	0	435.7	none	0
Vegetables	5,600.0	180,000 acres	3,800.0	0	3,800.0	none	0
Honey combs	20.0	5,679,000 supers	3,686.2	6,500.0	10,186.2	minor/none	0
Total	14,872.1	-	14,895.0 to 19,776.2	42,882.5	57,775.5 to 62,658.7	-	18,384.0

1/ 1978 dollars.
2/ Assumes reregistration of DBCP. If DBCP is permanently cancelled, economic impacts would range from approximately $379,000 to $610,00 annually.
3/ Including residential use.
4/ Primarily borne by the growers rather than the actual users. (APHIS Program of EDB).

An additional method, gamma irradiation, shows promise as a substitute for EDB post-harvest fumigation. However, as discussed above, the Food and Drug Administration has not reached a decision on approval of the use of irradiation on fruits and vegetables.

Loss of EDB may result in economic impacts to fruit and vegetable shippers, producers, and consumers. Shipper impacts would result from an approximate 700 percent increase in treatment costs, from $0.87 per 1,000 pounds of commodity using EDB to $6.25 per 1,000 pounds of commodity using either vapor heat or cold storage treatments. Changes in imports and exports of grapefruit, tropical fruits and miscellaneous vegetables would result in anestimated balance of trade deficit of $18 million annually, assuming Japan would not accept non-EDB treated grapefruit. However, if Japan agrees to accept grapefruit treated with alternative methods, this balance of trade deficit would be eliminated. These impacts are summarized by commodity as follows:

1. Grapefruit

Under current trade agreements, a cancellation of EDB could result in a loss of exports to Japan due to Japanese regulations which require EDB treatment. A loss of exports would result in decreased treatment costs of $263,300, while shipments of grapefruit by other shippers (imports and interstate) would result in increased treatment costs of $265,000 (vapor heat or cold storage), resulting in a net increase in treatment costs of $1,700. Under current trade agreements, the domestic market would have to absorb the grapefruit previously shipped to Japan (about 20 percent of domestic fresh consumption) which would result in price reductions and an estimated decrease in the annual value of production of over $29 million and a balance of payments loss of over $27 million. If Japan agrees to import grapefruit treated by alternative methods (vapor heat, cold storage, or gamma irradiation), the economic impacts of cancellation would be significantly reduced. Specifically, treatment costs of fruit exported to Japan would increase $1.6 million annually with the use of vapor heat or cold storage (changes in treatment costs with the use of irradiation have not been evaluated). Also, there would be no loss in the U.S. value of production (due to excess supplies) and the $27 million balance of payments loss would not occur.

2. Papaya

Cancellation of EDB could result in a loss of exports to Japan due to Japanese regulations requiring EDB treatment for papayas. A loss of exports would result in reduced treatment costs of $2,700 and a loss in revenue of $1.2 million. Interstate shipment would result in increased treatment costs of $73,500 for a net increase in treatment cost of $70,800. The alternative treatment methods of heat or cold would result in a high level of fruit damage. Although papayas would no longer be exported to Japan, the amount of fruit damaged would exceed the previous level of exports. Therefore, domestic supplies would decrease and prices of papaya would increase.

3. Mango

Cancellation of EDB would result in a loss of imports of mangoes. This loss would result in decreased annual treatment costs of $10,900. The domestic producers would not have competition from imports, resulting in short term price increases and an increase in the value of domestic (untreated) product estimated at $2,104,000 per year.

4. Other Citrus

Cancellation of EDB would result in increased treatment costs of $473,400 per year due to use of alternative treatments. The alternative treatments would result in product damage with a decrease of $2,003,000 in product value.

5. Miscellaneous Fruits and Vegetables

A cancellation of EDB would result in increased treatment costs of $7,600 due to use of alternative treatments. The alternative treatments would result in decreased value of product of $31,000 per year because of product damage from use of alternatives.

6. Summary of Quarantine Fumigation Impacts

The overall impact of EDB cancellation on the APHIS Quarantine Program would amount to an estimated increased annual treatment costs of $538,900 and an estimated decrease in the value of production of $24,800,800 per year. In the short term, consumers would have price decreases for grapefruit and price increases for papayas and mangoes. The magnitude of these increases was not estimated due to a lack of data. In the longer term, production adjustments would result in price changes that would partly offset the short term impacts.

Under current trade agreements, the cancellation of EDB usage in the APHIS quarantine programs would have an adverse impact on the U.S. balance of payments. This total impact, roughly estimated at $18.4 million, would eventually be borne by the consumer. The major factor would be the $27.4 million loss in the export market of grapefruit to Japan. In addition, export market of papayas to Japan, valued at $1.2 million, would be lost. Mangoes, valued at $8.2 million, would no longer be imported. Other imported commodities previously treated with EDB would be damaged, resulting in a $2.0 million positive impact on the balance of payment position.

D. Spot Fumigation of Grain Milling Machinery

EDB has been used for over 20 years as a spot fumigant for control of insect populations which invade flour milling equipment. Currently, an estimated 465,000 pounds of EDB active ingredient are used annually for this use. A 70 percent EDB and 30 percent methyl bromide combination is common, although other EDB formulations are also used. The only alternative spot fumigant that does not contain EDB is a mixture of 75 percent ethylene dichloride and 25 percent carbon tetrachloride. However, the dosage required for this pesticide is so large that the milling industry does not consider this mixture to be a viable substitute. It must be used more frequently (two to four times that of EDB fumigants) to exert any reasonable degree of control. The large amount of liquid material applied may cause the system to clog, requiring extra preparation time before milling can be resumed. The overall results of using this alternative mixture include the actual application of a much greater quantity of chemicals, a higher cost for fumigant, the use of more labor, and more down time of the mill. Carbon tetrachloride is also an RPAR candidate. If that compound were cancelled, then no spot fumigant would remain.

The only viable alternative to spot fumigation is general fumigation of the entire mill space. Methyl bromide and aluminum phosphide are currently the two most commonly used general space fumigants, accounting for approximately 75 and 25 percent, respectively, of the general space fumigant market.

The principal economic impact resulting from the cancellation of EDB as a spot fumigant in flour milling equipment would result from the increased cost of substituting general fumigation of the entire mill space (with methyl bromide or aluminum phosphide) for the current practice of spot fumigation of individual items of milling equipment.

It is projected that an average of four general fumigations per year would be required to achieve satisfactory control. The current practice is 12-14 spot fumigations and one general fumigation annually. Thus, the change would require that mills undertake three additional general fumigations per year but save 12-14 spot fumigations.

Based on the relative cost of the present versus the projected systems, the most likely increase in annual costs would be a total of $3,800,000 in the wheat, durum, and rye milling industries and $800,000 in the dry corn milling industry, respectively. These impacts would result in direct costs of $14,000 per year in wheat and rye mills and $8,600 in dry corn mills. Based on total human consumption of wheat, durum and rye flour, and dry corn mill products, the consumer impacts would be small, approximately 1.6 cents per person.

If five rather than four general fumigations are necessary per year, wheat nd rye mill costs would increase $6.4 million annually, and corn mill costs would increase $1.3 million annually, resulting in increased costs of approximately $21,500 and $14,000 per mill, respectively. Based on total human consumption of wheat, durum, and rye flour and dry cornmill products, the consumer impact under the more conservative estimates would continue to be small--approximately 2.8 cents per person per year.

E. Preplant Soil Fumigation

1. Tobacco

EDB is used to control root-knot, root lesion, and stunt nematodes on flue-cured tobacco in Flórida, Georgia, North Carolina, South Carolina and Virginia. Approximately 2.1 million pounds of EDB as an active ingredient were used in 1977, two-thirds of this in North Carolina.

Alternative registered chemicals to EDB include other fumigants (DD and Telone II), multi-purpose fumigants (Telone C-17, DD/Pic, Vorlex), and non-fumigants (ethoprop, fensulfothion, carbofuran and oxamyl). Even without use of EDB, nematodes could be eliminated, through an integrated pest management program involving rotation, setting healthy transplants, and early root and stalk destruction. Growers switching from EDB to other fumigants or from multi-purpose formulations containing EDB to other multi-purpose fumigants would not experience any significant change in yield regardless of nematode population levels, but the alternatives to EDB are more expensive.

If EDB were to become unavailable, tobacco growers would spend approximately $1.2 million more for control than they currently spend using EDB. These increased control costs represent an increase in total production costs of approximately 1.2 percent. Long run economic impacts to tobacco growers would be slight. Likewise, little if any impact would be noted at the market or consumer level if this registration of EDB were cancelled.

2. Pineapple

All commercial U.S. pineapple production is located in Hawaii, and all Hawaiian pineapple acreage must be treated with nematocides. Damage is caused either by the root-knot nematode or the reniform nematode. Approximately 572,400 pounds of EDB are used annually for nematode control on Hawaiian pineapple fields. The alternative to EDB is DBCP applied either in combination with DD or Telone. Depending on soil conditions and species of nematode present, each of these nematocides has its unique place in nematode control programs. EDB is used on approximately 11,500 acres subject to high soil moisture.

Since pineapple is a perennial crop (with a normal rotation of 4 years), only one-fourth (2,875) of the above mentioned 11,500 acres needs treatment annually. Substitution of a combination of DBCP and DD for EDB on this acreage would result in yield losses of approximately 4.8 percent, as well as increased control costs of about $98 per acre. 1979 price increases in DBCP relative to other nematocides could further increase these costs by $75 per acre since DBCP prices have increased from $9.35 to $20.00 per gallon. The present net value of the combination of these economic impacts, (estimated at 1977 dollars and prices) over the entire production cycle following removal of EDB (a 5 1/2 year period), is estimated at $5.3 million (using a 7 per cent discount rate). In the long run, approximately $1.5 million additional cost per year would be paid by Hawaiian pineapple growers until a satisfactory substitute for EDB is registered for use. Minor market or consumer impacts are expected.

3. Citrus

EDB is registered for preplant use in fruit tree planting sites, including citrus groves. Target pests are the citrus nematode and the burrowing nematode. EDB use in citrus (preplant) has been estimated at 20,000 pounds active ingredient annually. This quantity would treat approximately 110 acres, or less than one percent of new citrus acreage planted annually. The most viable alternatives to EDB for preplant citrus use are DD and Telone.

A second use of EDB in citrus is barrier establishment and maintenance to control the burrowing nematode in Florida conducted under a cooperative Federal-State Program. In this program, about 250,000 pounds active ingredient annually are chisel-injected in barrier zones ranging in width from 16 to 32 feet.

Economic impacts associated with cancellation of EDB for preplant use on citrus are expected to be minimal. In these preplant situations, use of alternatives will increase direct treatment costs by an amount ranging from $17.50 to $45.50 per acre depending on the alternative nematocide selected. However, because of the low volume use of EDB for this use site, total cost increases to affected growers will be only $3,500 per year. In the burrowing nematode control program, use of alternatives will increase program costs from $25,000 to $63,000 per year, depending on the alternative chemical chosen.

No short-term market or consumer effects are anticipated as a result of this EDB restriction. The long-run situation is less certain, especially if alternatives prove less effective for government-sponsored nematode containment programs. The extent of long-term impacts cannot be precisely determined, but should not be severe.

4. Peaches

EDB is used as a preplant nematocide on peaches. Primary target nematodes are ring, root-knot, lesion, and dagger nematodes. Prior to the suspension of DBCP, approximately 170,000 pounds of EDB active ingredient were used annually, enough material to treat about 2,000 acres of peaches. Almost all of this usage has been in the East, where over 13,000 acres of peaches are planted annually. Prior to the 1979 suspension, DBCP was used to treat an additional 8,325 acres annually. If the suspension of DBCP becomes a permanent cancellation, EDB would be the preferred chemical on these acres.

Registered alternatives to EDB for use in peach orchards are numerous, and include DBCP (temporarily suspended), DD, Telone, Vorlex, methyl bromide, zinophos, and chloropicrin. The major alternatives (DBCP, DD, and Telone) are equal in efficacy to EDB.

If DBCP use is allowed to continue on peaches, increased grower costs on the 2,000 acres currently treated with EDB would range between $20,300 and $118,180 annually ($10-$59 per acre), depending on the alternative chemical of choice (DBCP, DD, or Telone). However, if DBCP is permanently cancelled and EDB is assumed to be the preferred chemical on 10,325 acres, grower costs of an EDB cancellation would range from $378,700 to $610,100 annually (approximately $37 to $59 per acre) depending on the alternative chemical of choice (DD or Telone). At the industry level, the increased costs are not significant under either scenerio (with and without DBCP). No significant market or consumer impacts are expected if EDB becomes unavailable to peach growers.

5. Peanuts

About 17 percent of peanut acreage in the major U.S. peanut-producing regions is currently treated with EDB, resulting in annual EDB usage of approximately 4.2 million pounds of the active ingredient.

There are several registered alternatives to EDB for use on peanuts, although none are equally effective. The major liquid fumigant alternatives are Telone II and DD. Viable granular alternatives are Furadan, Dasanit, Mocap, Nemacur, and Temik, all of which are applied at planting. Each of thesealternatives is more expensive than EDB. It is estimated that substituting one of the several alternatives (choice of the particular alternative being dependent on many biological factors) for EDB would result in increased control costs to peanut growers of approximately $2.5 million per year.

More important than increased control costs is decreased value of production. If granular alternatives are used, yield losses of 6 percent are estimated due to reduced efficacy. If liquid formulations are used, yield losses will vary geographically from 7.5 to 8.0 percent. In the latter case, yield losses because of a required 10 to 14 day planting delay required to prevent phytotoxicity to the peanut plant. These yield losses would reduce producers' revenues by $11 million per year in addition to the $2.5 million per year increase in control costs. However, government price support programs are expected to prevent these losses from influencing consumer prices.

6. Cotton

EDB is registered for use throughout the cotton belt. An estimated 721,800 pounds were used in 1977, primarily to control the root-knot nematode. However, since that time, the suspension of DBCP may have increased usage to 1.6 million pounds annually. Telone II and DD remain as viable alternatives, and are equally effective under good soil conditions.

The only economic impact expected from cancellation of EDB would be an increase in cost of control, from $13.75 per acre with EDB to about $21.00 per acre with any of the alternatives. At an application rate of 2.5 gallons per acre (12.1 pounds a.i per gallon), an estimated 55,560 acres are treated annually with EDB. Use of substitutes for EDB on these acres would increase treatment costs by $435,700 per year. Compared to the approximate $3 billion value of the U.S. annual cotton crop, these increases are negligible. Accordingly, no measureable market or consumer impacts are projected.

7. Vegetables

Approximately 180,000 acres of various vegetables (broccoli, carrots, cauliflower, cucumbers, eggplant, lettuce, lima beans, melons, okra, potatoes, squash, strawberries, and tomatoes) are treated by preplant soil fumigation with EDB to control nematodes. Depending on the crop in question, EDB is applied at rates of 1.5 to 6.0 gallons per acre. An estimated 5.6 million pounds a.i. EDB are used annually.

Alternatives to EDB (Vorlex, DD, and Telone II) are considered equally effective. The loss of EDB on vegetables would result in increased pest control costs to vegetable producers of $3.8 million per year. There would be no loss in vegetable production due to the cancellation of EDB. Given a producer value of these vegetables of about $3 billion, the increased costs of the alternative fumigants would not have a significant impact on prices of these vegetables.

Producers of melon, lima beans, tomatoes and cucumbers would incur the largest impacts. This is due to the number of acres of these crops treated with EDB. On a per acre basis, the increased costs range from $6.88 for carrots to $28.90 for cucumbers.

Table 28 shows costs of alternatives to EDB on vegetable crops.

No significant market or consumer impacts are expected if EDB were not available for use on vegetables.

F. Minor Uses

1. Fumigation of Felled Logs

Several bark beetle species in the West attack coniferous trees and cause damage which can be reduced through the use of EDB. The alternatives are lindane and endosulfan. However, lindane is not considered a viable alternative because it is in RPAR review and the lindane PD 2/3 recommends its

Table 28

Alternative Nematocides Used to Replace EDB on Selected Vegetables, Cost of Materials and Changes in Nematode Control Cost, by Crop [a]

Crop	With EDB	With alternative nematocides				Increase in nematode control costs	
		D-D	Vorlex	Telone II	Total	Total	Per Acre
	$1,000						
Broccoli	51	85	—	91	176	125	22.64
Carrots	381	285	—	202	487	106	6.88
Cauliflower	10	6	—	30	36	26	23.01
Cucumbers	201	269	420	143	832	631	28.85
Egg Plant	5	11	4	1	16	11	22.00
Lettuce	5	9	—	7	16	11	22.00
Lima Beans	248	462	—	492	954	706	23.57
Melons	330	724	—	406	1,130	800	23.11
Okra	59	129	67	27	223	164	25.57
Potatoes (white) [b]							
A. Wash.Idaho	990	510	—	648	1,158	168	16.80
B.Other States	91	152	—	122	274	183	18.48
Potatoes (sweet)	214	291	—	—	291	77	11.85
Squash	11	6	10	26	42	31	25.83
Strawberries	15	16	—	35	51	36	22.50
Tomatoes	312	524	—	558	1,082	770	22.65
Totals	2,923	3,479	501	2,788	6,768	3,845	—

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[a] Application rates, material cost per gallon, and the alternative nematocides used were specified by the EDB Assessment Team based on product labels, State recommendations, efficiency of registered alternatives, and material costs per acre. The application rates and material cost per gallon are as follows:

Current control program:

EDB: 1.5 gallons per acre for lima beans; 4.5 gallons per acre for carrots; 6 gallons per acre for sweet potatoes and 1.67 gallons per acre for the remaining vegetables (12 pounds a.i. at $5.50 per gallon).

Terr-o-Cide: EDB 6 gallons per acre (8.43 pounds EDB and 7.03 pounds chloropicrin) at $16.50 per gallon.

Alternative control program:

D-D: 16 gallons per acre for sweet potatoes, and 11 gallons/A for remaining crops (10 pounds a.i.) at $2.80 per gallon.

Vorlex: 6 gallons per acre (11 pounds a.i.) at $8.00 per gallon.

cancellation for this use. Limited information indicates that endosulfan is less effective than EDB. Nonchemical controls, such as good silviculture practices, careful site selection, avoidance of monoculture, and thinning and removal of diseased or injured trees are also effective. However, during pest epidemics, chemical control may also be required.

Records show that in FY 1977, approximately 20,000 pounds of the active ingredient of EDB were used in Colorado and North Dakota only. Data for other areas are not available. At label rates, this is sufficient material to treat about 68,000 trees. EDB is used to treat trees that have already been attackedby bark beetles after the damaged tree has been cut. It is applied as an "open" log spray or under a plastic covering.

The extent to which EDB has been used for forestry purposes is not sufficient to appreciably affect commercial timber harvests. Rather, EDB is generally used where bark beetle damage may have aesthetic impacts to residential areas, wildlife habitats, or recreational areas. Such impacts are difficult to quantify, but typical residential lots suffering tree mortality from mountain pine beetle infestation could lose from $1,500-$3,000 in value.

Cost of control could be reduced by as much as $36,000 per year if endosulfan were to replace EDB; however, endosulfan may not be as effective as EDB.

2. Termite Control

EDB is the only pesticide registered by EPA as a fumigant for subterranean termite control. EDB is also state-registered in California for the control of drywood termites. Alternatives registered for control of subterranean species include aldrin, dieldrin, chlordane, heptachlor, pentachlorophenol (under RPAR review), and chlorpyrifos. For drywood species, registered alternatives include methyl bromide, sulfuryl fluoride, hydrogen cyanide, pentachlorophenol, and silica aerogel.

Estimates of EDB use vary from 5,000 to 12,000 gallons of formulation, or approximately 11,500 pounds to 27,600 pounds of the active ingredient per year. It is estimated that approximately 12,400 homes were treated with EDB for subterranean termite control in 1977. No data were available indicating units treated for drywood termite control.

Economic impact data regarding the use of EDB and alternative insecticides are limited; therefore, the magnitude of user, market, and consumer impacts cannot be precisely identified. Because the current use of EDB is small relative to other insecticides, overall impacts should be minor. However, certain homeowners, particularly in the southeastern and the southwestern U.S., who may experience difficulty in controlling subterranean termite infestations, could incur substantial losses. Because of the need to apply a fumigant into holes drilled in concrete foundations, there are no known chemical alternatives for homeowners in the Southeast and Southwest. The only known solution in this case is removal of the infested wood and rebuilding.

3. Fumigation of Stored Beehive Supers and Honeycombs

Honeycombs being stored between honey producing seasons are fumigated with EDB to control the larvae of the greater wax moth (GWM), which damage the waxcomb and bases held mounted on frames by hive supers.

Alternatives to EDB for this use are paradichlorobenzene (PDB) and carbon dioxide. In the North, cold weather is a natural control. Paradichlorobenzene is more practical to use than carbon dioxide, as the latter requires elaborate monitoring equipment to ensure efficacy and safety for the user. Paradichlorobenzene is somewhat less effective than EDB because it does not provide control of the egg stage of the GWM.

The use of PDB to replace EDB in the treatment of honeycombs will increase beekeeping costs by about $3.7 million annually. The cost per super treated will increase about 5 cents -- 4 cents with EDB versus 9 cents with PDB. Further, with PDB and CO_2 there would be 7 additional treatments needed per super.

Using the next best alternative, PDB, it is estimated that the volume of marketable honey would be reduced 20 percent in a super previously treated with EDB. This loss is due to decreased control of the GWM larvae which damage the honeycomb; in turn, the damaged honeycomb must be replaced with a fresh comb base prior to use in the hive during honey flow. Approximately one-third of all supers in the nation would be treated for the GWM using PDB in place of EDB. The total quantity of domestic honey would thus be reduced by 6.67 percent.

Annual honey production in the U.S. during 1975-77 averaged 191 million pounds. Based on a 6.67 percent reduction in honey production without EDB, the annual loss to beekeepers would be 12.7 million pounds, valued at $6.5 million.

To some extent, a production loss of this magnitude will result in higher consumer prices, thus shifting some of the impact of EDB cancellation from the producer to the consumer. The extent of this consumer price impact cannot be estimated.

In addition to these economic impacts, there will probably be some losses attributable to the reduced pollination service which bees provide. It is estimated that pollination services of honey bees are valued at $6 billion annually. Because the alternatives are not as effective as EDB, there will be some losses in pollination capacity resulting from the reduced number of colonies. It is not possible to estimate the impact on pollination which could result from the cancellation of EDB.

4. Fumigation of Stored Clothing and Furniture

Two products containing 5% EDB are registered for use in vault fumigation to control clothes moths attacking furs, woolen garments, rugs, carpets, linen, mohair, or upholstered furniture. The directions for one product state, "Use T-H Vault fumigant in a standard fumigation system, designed for evaporation of a liquid fumigant in a fur storage vault or de-mothing cabinet." This entails pouring the liquid fumigant into a small flat container within the vault and, depending upon the fumigant being used, placing the container near the ceiling or on the floor. The fumigant then evaporates and the gaseous fumes fill the vault to penetrate items being treated. Both product labels carry statements of caution regarding handling and operator protection and safety. Also, both products bear one or the other of the statements: "Not for household use" or "For pest control operators only."

Four alternatives to EDB were found for this use. The first is a mixture of carbon tetrachloride and ethylene dichloride in a ratio of 3 to 7. Since carbon tetrachloride is undergoing RPAR review, this alternative is not considered fully viable.

The second registered alternative is chloropicrin. It is a disagreeable material with which to work, but this property tends to discourage mishandling and exposure.

Methyl bromide is the third alternative. The three registered methyl bromide products also contain 0.25 to 2% chloropicrin, as an odor warning agent. For methyl bromide, the term "vault fumigation" would have to be interpreted liberally, because the labels cite barns, storage buildings, and other structures infested with these pests. Extreme care must be exercised before applying methyl bromide, because it reacts with a number of organic materials to produce foul-smelling odors. These materials include furs, feather pillows, leather goods, and a variety of woolens.

The final chemical registered for this site/pest combination is sulfuryl fluoride. Two products are registered, both containing 99% active ingredient. This chemical, like methyl bromide, is released as a gas through copper tubing from a pressure tank into the structure being fumigated. The economic impacts of EDB use on vault fumigation were not evaluated but are expected to be small.

5. Fumigation of Quarantined Plants, Soil and Grass Sod

The Japanese Beetle Domestic Quarantine program (7 CFR 301.48) requires the treatment of regulated articles (including such material as soil, balled plants and grass sod). Ethylene dibromide #440 (20% EDB), miscible ethylene dibromide #434 (2.5% EDB), and methyl bromide are authorized fumigants for these regulated articles to control the Japanese beetle. Because chlordane has been cancelled for all uses other than structural termite control and dipping the roots and tops of non-food use plants, it is limited only to some uses cited below. Therefore, methyl bromide is the single alternative used for comparison.

Labels for these EDB-containing products do not specify that use be restricted to certified applicators only, but do caution against inhaling, swallowing, skin contact, vapors near eyes, or contamination with feed and food stuffs.

Applications of EDB and methyl bromide for each of these articles are detailed below.

Grass sod: EDB #440 (20%) or #434 (miscible, 2.5%) is mixed at 20 cc EDB to 1 gallon of water, sprayed over the sod and left to stand undisturbed for 24 hours. This amounts to 20 lbs. of EDB per acre treated.

Methyl bromide is applied to cut, stacked, or rolled sod, under a tarp and left to stand for 3 hours. The average rate of treatment is 2.5 lbs a.i. per 1000 cubic feet or 60 pounds methyl bromide per acre under a tarpaulin.

Bare root plants: EDB #440 (20%) is mixed at 12 cc per gallon of water and the plant roots are soaked in the solution 24 hours. Methyl bromide application is 2.5 lbs/a.i. per 1000 cubic feet under a tarpaulin.

Plants Balled or in Containers: #440 EDB (20%) is mixed at 2 cc per gallon of water to be used as a dip or 2.5 cc per gallon of water to be poured on. Plants are then left undisturbed for 24 hours. There is also an injection method which is not ordinarily used at the present time. At this rate, 1.65 lbs. of EDB are used per 1000 cubic ft. of soil in balled and containerized plants. Methyl bromide is applied at a rate of 2.5 lbs. per 1000 cubic ft. under a tarpaulin.

Potting and bench soil: 50 cc of #440 is mixed in 3 gallons of water per cubic yard of soil (65 cc in 6 gallons of water for high organic soil). The soil is treated in 12 inch layers and soaked for 48 hours. Present annual usage amounts to less than 50 gallons of the formulation. (USDA, 1978). Methyl bromide is applied at a rate of 2.5 lbs. per 1000 cubic feet for 3 hours under a tarpaulin.

The economic impacts of the alternatives have not been evaluated. Fumigation chambers or technology are not generally available to nurserymen who are involved in this treatment on only an occasional basis.

IV. Identification of Regulatory Options

A. Introduction

As explained in Part I, FIFRA mandates the Agency to weigh the health risks and economic benefits of each use of a pesticide in order to achieve a balance between these competing considerations. In Chapters II and III, the Agency identified the risks posed by exposure to EDB and the benefits derived from each of its registered uses. To achieve a risk/benefit balance, the Agency has identified a number of regulatory options, and has evaluated each option for its impacts on both sides of the risk/benefit equation.

In addition, the Agency has evaluated the risks of alternative pesticideswhich have been identified as viable options for the various uses of EDB.

This section identifies the regulatory options available to the Agency to reduce the risks from the registered uses of EDB. The legal authorities for these options as provided in FIFRA are also discussed. In Chapter V of this document, each option will be evaluated for its impact on the risks and benefits of each registered use of EDB. These changes will then be compared to determine the most appropriate regulatory option for the specific registered use being examined.

B. Legal Basis for Options

FIFRA provides the Administrator with three broad legal courses of action for the registration of a pesticide. These are cancellation, continued registration without restrictions, and continued registration with restrictions.

Cancellation and continued registration without restrictions are opposite courses of action which hinge on a determination that a pesticide does or does not cause unreasonable adverse effects. To make this determination, the Administrator weighs the risks and benefits of each use of a pesticide. If the risks of a use outweigh the benefits, and the risks for that use cannot be lowered, the use may be cancelled. If the benefits of a use outweigh its risks, and any actions taken to reduce the risks result in a significant reduction in benefits, the registration of that use may continue. In the case of cancellation, the Administrator issues a notice of intent to cancel any or all registrations of a pesticide [FIFRA Section 6(b)(1)]. This cancellation notice becomes effective within 30 days, unless a registrant requests a hearing regarding its registrations. In the case of continued registration without restrictions, the Administrator may publish a final RPAR position document stating a rationale for choosing that course of action.

Between these polar alternatives of cancellation and continued registration without restrictions exists a whole range of possible regulatory actions. In fact, FIFRA requires the Administrator to "consider restricting a pesticide's use or uses as an alternative to cancellation...." [FIFRA Section 6(b)]. Although FIFRA does not specify what kinds of restrictions are to be examined, the Agency interprets this to mean amending the terms and conditions of registration in any fashion necessary to lower exposure (and consequently risk) to the point that benefits are greater than the risks, and the reduction in risks has not resulted in a significant reduction in benefits.

C. Data Gathering for Identification of Options

In the process of varying the terms and conditions of registration, the Agency can create an array of regulatory options intermediate to those of cancellation and continued registration without restriction. In order to facilitate the development of viable regulatory options, FIFRA provides the Agency with certain legal "tools" to be used in the process of gathering information on available options. The legal "tools" which FIFRA provides for developing intermediate options are:

1. Additional data

Under FIFRA section 3(c)(2)(B), the Administrator may require a registrant to submit any additional data necessary to maintain an existing registration. When reviewing an RPAR pesticide, the Agency may identify areas in its risk and benefit analyses where data are inadequate or totally lacking. The Administrator may then require a registrant to provide specific data within a certain time; if the registrant fails to comply, his registrations may be suspended.

2. Information-Gathering Hearings

If the Administrator is uncertain whether to cancel or restrict a pesticide, s/he may publish a notice of intent to hold a formal hearing to resolve the issue [FIFRA Section 6(b)(2)]. At the end of this hearing, the Administrator makes a decision based on the hearing record. As an alternative to a formal hearing, the Agency may conduct an informal hearing to gather information, [FIFRA Section 21(b)] and then use that information to propose a recommended decision.

D. Legal Options Available Under FIFRA

The following regulatory options are available to the Administrator under FIFRA to reduce the risks from the registered uses of a pesticide:

1. Classification for Restricted Use

FIFRA Section 3(d) enables the Administrator to restrict a pesticide's use(s) if such use(s) cause unreasonable adverse effects. This classification means that the pesticide may only be applied by or under the supervision of a certified applicator, one who is trained and approved by a state as competent to use restricted pesticides.

In classifying a pesticide for restricted use, the Administrator may also propose other restrictions specific to each use of the pesticide. The additional restrictions are aimed at reducing the risk to the general population and applicators. These other restrictions are discussed in Section E of this chapter.

2. Amend the Terms and Conditions of Registration

Under FIFRA Section 6(b)(1), the Administrator may offer the registrant the option of voluntarily amending the specific registered uses of a pesticide for which unreasonable adverse effects exist. Rather than to cancel all uses of the pesticide, the voluntary change in classification would permit the registration to be continued for certain uses which do not cause unreasonable adverse effects and it would be cancelled for those uses where unreasonable risks are present.

3. Labelling

FIFRA Section 3(c)(5) specifies that the label and labelling of a pesticide must comply with the requirements of FIFRA. That is, the label must not have use directions which result in unreasonable adverse effects. Consequently, the Agency may require a registrant to amend the label in order to keep the label in compliance with FIFRA. Examples of label changes include requiring protective clothing and/or respirators, warning applicators of the toxicological hazards of the pesticide, altering the application rates or methods, and other use or handling directions which are designed to reduce applicator exposures.

4. Establish or Re-evaluate Tolerances in Conjunction with FDA

Section 408 of the Food, Drug and Cosmetic Act requires that the Administrator, under recommendation from recognized experts qualified to evaluate pesticides, establish a tolerance for residues of a pesticide on raw agricultural commodities. Also, the Administrator may require that the registrants submit data in the form of a petition for tolerance according to the recommendations of an advisory committee.

The data required under Section 408 to establish a tolerance are:

(A) the name, chemical identity, and composition of the pesticide chemical;

(B) the amount, frequency, and time of application of the pesticide chemical;

(C) full reports of investigations made with respect to the safety of the pesticide chemical;

(D) the results of tests on the amount of residue remaining, including a description of the analytical methods used;

(E) practicable methods for removing residue which exceeds any proposed tolerance;

(F) proposed tolerances for the pesticide chemical if tolerances are proposed; and

(G) reasonable grounds in support of the petition.

Should the Administrator cancel certain uses of a pesticide, s/he may revoke the established tolerance for that pesticide on the basis of the data supporting cancellation [40 CFR 180.32].

5. Cancel After a Specified Period of Time

If the Administrator determines that certain uses of a pesticide chemical cause unreasonable adverse effects, then s/he would issue a notice of intent to cancel those uses. If s/he also determines that there are no effective pesticide or nonchemical pest control methods currently available as effective alternatives to EDB, the Administrator could delay cancellation for a specified period of time to allow for development of alternatives. Such a decision would be implemented by issuing a notice of intent to cancel [FIFRA Section 6(b)(81)] and by conducting a formal hearing if requested.

In summary, FIFRA provides the Administrator with several legal authorities for regulating RPAR pesticides. With this legal foundation established, the Agency next must explore possible technical use restrictions (i.e., amendments to the terms and conditions of registration), and evaluate the extent to which these restrictions would reduce the risks of EDB.

E. Risk Reduction Measures for EDB

1. Use Restrictions for All Uses of EDB

This section presents the use restrictions which could apply to all uses of EDB. The restrictions listed here are intended to reduce exposure to applicators, other persons, and animals during and after fumigation. This section is intended only to present all of the potential options developed by the Agency, and not to indicate a decision to impose specific options. Sections following this one present additional restrictions specific to each use pattern. These additional restrictions are intended to reduce both applicator exposure and food residue exposures.

a. Classify EDB for Restricted Use

Due to the chronic hazards posed by EDB, the Agency could classify this pesticide for restricted use. Under this classification, only certified applicators or persons directly under their supervision would use EDB. A standard statement to this effect would appear on the label.

b. Protective Clothing

To prevent dermal contact with EDB, applicators could be required to wear boot covers, disposable gloves and an apron during transfer of the pesticide (i.e., pouring), during calibration or maintenance of application equipment, or during clean-up of spills. These protective articles must be made of a material resistant to EDB penetration. Butyl rubber is recommended for use in gloves. Nitrile and polyethylene, while less resistent, are sufficient for use in aprons, coveralls and boot covers where close body contact does not occur. Articles made of natural rubber or leather should not be used. Contaminated clothing should be removed immediately and exposed skin washed with soap and water. Gloves and boot covers would be thrown away immediately if contaminated, or after each use (not to exceed one hour) in any event. Other clothing would be commercially laundered daily, or aired for at least 24 hours. All of these requirements would appear on the label.

c. Respirator

A respirator could be required to be worn at all times during application and when reentering the treated site throughout the specified reentry period. A full-face black canister gas mask approved by NIOSH/MSHA for removing organic vapors could be used. Applicators would be trained to properly wear, maintain, and store a respirator. The black canister or charcoal filter is to be replaces after each day or use. All of these requirements would appear on the label.

d. Reentry Period

Before application, signs would be required to be posted at entrances to the treated area (i.e., treated field or building) bearing the signal word "DANGER," the product name, date of treatment, treatment period (if applicable), the date when reentry is allowed, and what protective equipment is required. The sign would remain posted during application and throughout the period before reentry is allowed. The label would also contain this information. Sample warning statement might read:

> FOR OUTDOOR FUMIGATION:
>
> DANGER
>
> SOIL FUMIGATED WITH (PRODUCT NAME) ON (DATE). DO NOT REENTER TREATED AREA UNTIL (REENTRY DATE) OR UNTIL EDB AIR LEVEL IS LESS THAN 0.4 PPM . WEAR A FULL FACE BLACK CANISTER RESPIRATOR IF YOU MUST REENTER THIS AREA BEFORE THE POSTED REEN[illegible] INTERVAL.
>
> FOR INDOOR (SPACE) FUMIGATION:
>
> DANGER
>
> PREMISES FUMIGATED WITH (PRODUCT NAME) ON (DATE). TREAMENT PERIOD LASTS UTIL (DATE). WEAR A FULL FACE, BLACK CANISTER RESPIRATOR BEFORE REENTERING PREMISES. AFTER TREATMENT PERIOD, OPEN ALL WINDOWS, DOORS AND VENTS. REENTRY WITHOUT A RESPIRATOR IS ONLY PERMITTED AFTER 24 HOURS OF AERATION OR WHEN EDB AIR LEVEL IS BELOW 0.4 PPM.*

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* 0.4 ppm is the lowest level at which an IR detector alarm can sense the presence of EDB. These detectors are available from the Foxboro Company, Wilkes Infrared Center, S. Norwalk, CT.

e. Warning of Chronic Risks

The label would indicate that EDB poses a risk of cancer and mutagenic effects to humans in addition to the acute effects already described on the label. A sample sentence is:

> "EDB HAS CAUSED CANCER, MUTAGENIC EFFECTS AND REPRDUCTIVED DISORDERS IN LABORATORY ANIMAL TESTS AND MAY PRESENT THESE HEALTH RISKS TO HUMANS".

f. Other Safety Precautions

The label would also include statements expressing the following requirements:

- Fumigation may take place only when personnel will not be in the area (i.e., treated field or building) during the treatment period and the reentry period. Humans and animals must be vacated from treatment area before fumigation;
- EDB may not be used or stored in domestic dwellings;
- Soap and water must be available for washing skin or flushing eyes in case of contact with EDB;
- Hands must be washed before eating or smoking;
- Transferring activities (i.e., pouring) must be conducted outdoors, unless a closed system of transfer is used;
- Spills must be cleaned up immediately. If a spill is on soil, cover with six inches of soil. If a spill occurs on other surfaces, remove EDB with an EPA-approved cleaning agent;
- Pesticide containers are disposed of by either burying in a State-approved pesticide disposal site or by returning them to a container reprocessor;
- Containers or equipment made of aluminum, magnesium, or their alloys must not be used, because EDB will corrode them.

2. Additional Requirements for Soil Fumigation Uses

Reentry Period. Reentry without full-face, black canister respirator into treated area will not be permitted until 24 hours after fumigation is completed. This information would appear on the label and on warning signs posted around treated areas. This requirement would supersede the minimum use restriction mentioned previously in that it proposes a specific reentry time interval. The reentry interval is based on data indicating that EDB level are below the level of detection at 24 hrs. after fumigation.

3. Additional Requirements for Stored Grain Fumigation

a. Restrictions for Reducing Applicator and Reentry Exposure

1) Protective Clothing

EDB-resistant gloves (butyl rubber), boot covers and apron (butyl rubber, nitrile, or polyethylene) would be required at all times during fumigation.

This requirement would supersede the minimum use restriction of wearing protective clothing only during mixing and loading, etc. The label would describe this additional requirement.

2) Use Directions

Before fumigation, all leaks and vents in the grain storage structure (e.g., bins, flats, elevators, boxcars or other storage facilities) would be required to be sealed with masking tape, caulking or plastic. Humans would be vacated from the structure to be treated. Only devices which apply the fumigant quickly, evenly and with minimal vaporization would be permitted (such as a sprinkling can without a nozzle or a coarse stream power sprayer). After fumigation is completed, the treated structure would be sealed and all entrances locked. The label would describe these requirements.

3) Reentry Period

After the treatment period has elapsed, a respirator could be required to be worn upon reentry, all doors and windows opened, and aeration systems activated (if available). Reentry without a respirator would be permitted only after 24 hours of aeration or until an IR detector indicated a concentration of EDB in air no more than 0.4 ppm. The label and posted warning signs would bear this information.

4) Placarding Treated Grain

Treated grain transported to another location would be placarded with a sign indicating the date of last treatment. This sign could be removed at the grain's destination. The purpose of this use restriction is to warn grain inspectors and other workers of the previous use of a fumigant in a particular grain shipment. The label would include this restriction. As a further safety measure, grain inspectors would use an IR detector to determine whether transported grain contained levels of EDB gas in excess of 0.4 ppm. If levels were to exceed 0.4 ppm, grain would be held in quarantine at the elevator until EDB gas measurements were below the 0.4 ppm level.

b. Restrictions for Reducing Food Residues

1) Require a Holding Period for Treated Grain

EDB slowly dissipates from treated grain held in storage. To allow EDB residues to dissipate, the Agency will consider requiring holding periods of 30, 60, or 90 days for treated grain. If a holding period were imposed, it would be stated on the label and on the placard that accompanied the transported grain. Tolerances would be established, or changes in labelling would be made to enforce this requirement.

2) Prohibit "Off-Farm" Fumigations (Country Elevators, Terminal Elevators, Boxcars, Trucks, Mill Storage, etc.).

Because "off-farm" use of EDB contributes about 3/4 of the dietary risk from grain, the Agency could prohibit these uses. The only uses on grain which would be permitted under this restriction would be "on-farm" fumigation of grain stored in warehouses, bins, or under tarpaulins. If this restriction were imposed, it would be required to appear on the label. Tolerances would be revised or changes in labelling could be imposed to enforce this measure.

3) Prohibit "Off-Farm" Use and Prohibit "On-Farm" Treated Grain from Being Used for Human Consumption

To eliminate direct dietary exposures of EDB through treated grain, the Agency will consider prohibiting the use of treated grain for direct human consumption. To ensure that this restriction is followed, registrants would be required to add an FDA-approved dye to their products; grain treated with EDB would then be discolored and identifiable as illegal for human consumption. This requirement would have to appear on the label. Tolerances would be revised or changes in labelling could be imposed to enforce this measure.

4. Additional Requirements for Spot Treatment of Milling and Cereal-Handling Machinery

a. Use Restrictions for Reducing Applicator and Reentry Exposure

1) Protective Clothing

EDB-resistant gloves (butyl rubber), boot covers and apron (butyl rubber, nitrile, or polyethylene) would be worn at all times. The label would state this.

2) Use Directions

Before fumigation, milling equipment would be run dry to minimize the amounts of flour and grain parts left in the machinery. Persons not involved with the fumigation would be vacated from the building. Only a "closed system" hand-held applicator gun or an automatic dispensing system would be used to apply EDB. Open pouring or pouring into bottles would be prohibited. After completing fumigation, all windows, doors, vents and entrances would be locked shut. These requirements would appear on the label.

3) Reentry Period

After the 24 hour treatment period, a respirator would be required to be worn to reenter the building. All doors, windows and vents would be opened at this time. Before anyone could reenter the treated building without a respirator, the premises would be aerated 24 hours or until an IR detector showed that EDB air levels are below 0.4 ppm. The Label and posted warning signs would bear this information.

b. Restriction for Reducing Food Residues

Prohibit a Quantity of Contaminated Flour from Being Used for Human Consumption. After spot treatment a mill could require several hours to start producing flour of acceptable quality. This first batch of flour is normally separated and then slowly fed back into the flour stream. Because a significant portion of the EDB residues resulting from spot treatment occur in this start-up batch, the Agency would require that the batch of flour be discarded. This requirement would appear on the label.

5. Additional Requirements for Post-Harvest Fumigation of Citrus and Tropical Fruits

a. Engineering and Operational Changes for Fumigation Facilities.

The Animal and Plant Health Inspection Service (APHIS) of the U.S. Department of Agriculture (USDA) regulates all fumigation centers in the U.S. and two centers in Mexico. APHIS regulations and its treatment manual would be revised so that each fumigation center meets a standard of a maximum permissible level of EDB concentration in air of 0.4 ppm (15 min. avg.). To meet this standard, APHIS could implement any of the following risk reduction measures to achieve the air standard in addition to those which appear on the label (See Section IV. E. above):

-Closed dispensing system (EDB-resistant tubing with soldered connections), including an air coupling (with which to purge the line before opening it), and a pressure relief valve. Valves would be designed for handling EDB.

-Air monitoring device with an IR detector connected to an alarm and calibrated to be triggered if the EDB air levels in the hallway exceed 0.4 ppm.

-Ventilation system would be adjusted so that there is greater pressure in the hallway than in the fumigation chamber.

-Training of applicators in all aspects of fumigation procedures, protective equipment, safety precautions and emergency plans.

-Testing of fumigation chambers for leaks before the USDA inspector approves a fumigation permit.

-Restarting exhaust fan after opening chamber door to move EDB vapors away from workers.

-Monitoring of personnel to detect EDB exposure levels on a scheduled basis.

-Posted operating instructions and emergency procedures.

b. Requirements for Warehouses Holding Treated Commodities.

APHIS is responsible for reducing exposures that result from treated fruit as it is transported or stored. Because high exposures have been detected during warehouse workers' handling of treated fruit, APHIS could require these warehouse facilities to meet the standard of 0.4 ppm EDB in air. This would involve:

-Monitoring of personnel to detect EDB exposure levels on a scheduled basis.

-Installation of ventilation systems in warehouses adequate to ensure that exposure does not exceed 0.4 ppm.

-Installation of detection/alarm devices in warehouses calibrated for 0.4 ppm.

-Requiring full-face, black canister respirators for all personnel who are exposed to EDB air levels higher than 0.4 ppm. (For instance, the "stickmen" who unload treated citrus from trucks would have to wear a respirator unless the cardboard containers are eliminated.)

-Replacement of cardboard citrus boxes with a bulk loading system made of a non-EDB-absorbent material. (This requirement would be optional. However, a bulk loading system may reduce exposure to less than 0.4 ppm and thereby eliminate the need for workers to wear respirators.)

-Training of all warehouse personnel about hazards of EDB, methods for reducing exposure, and emergency procedures.

-Signs would be posted in warehouses stating:

> WARNING - FUMIGATED FRUIT MAY EMIT HARMFUL ETHYLENE DIBROMIDE VAPORS. IF AIR LEVELS BECOME HAZARDOUS AND ALARM SOUNDS, PUT ON FULL-FACE BLACK CANISTER RESPIRATOR IMMEDIATELY.

c. Restriction for Reducing Food Residues

Require treated fruit to be stored for a specific period. One approach to reducing EDB residues in treated commodities is to lengthen the treatment-to-market interval by requiring treated fruit to be stored for a certain period after treatment. Based on the available data the Agency has estimated a degradation formula for EDB residues in treated fruit. Using this formula for citrus, EDB residues are estimated to decrease from 8 ppm to 1.42 ppm during a six-day treatment-to-market interval. If this treatment-to-market interval were lengthened, EDB residues could be further reduced. To explore the feasibility of this approach the Agency could require APHIS to hold treated fruit from commerce for a certain time period. This requirement would be stated on the label.

6. Additional Requirements for Fumigation of Beehive Supers

a. Use Restriction for Reducing Applicator and Reentry Exposure

1) Protective Clothing

The label would state that EDB-resistant gloves (butyl rubber), boot covers and apron (butyl rubber, nitrile or polyethylene) would be worn at all times.

2) Use Directions

Hives and/or combs (supers) would be placed in a gas-tight room or under a gas-tight covering such as a polyethylene tarpaulin held down with sand-filled "snakes". All windows, doors and vents would be sealed. All persons not involved with the fumigation would be vacated from the building. The label would state these directions.

3) Reentry Period

Following the treatment period, a full-face black canister respirator would be worn when reentering. All doors, windows and vents must be opened at this time. Aeration for 24 hours or until EDB air levels are less than 0.4 ppm, measured by IR detector, shall be required before reentry is permitted. The label and warning signs would contain this information.

b. Restriction to Avoid Food Residues

Limit fumigation to beehive supers that are clean and in storage. To avoid possible contamination of honey or honeycombs, the label would prohibit treatments other than on clean supers in storage. This restriction is in accordance with current practice.

7. Additional Requirements for Vault Fumigation of Stored Clothing.

a. Use Restrictions for Reducing Applicator and Reentry Exposure

1) Commercial Use Only

Vault fumigation would be conducted only by certified commercial applicators in commercial clothing storage vaults. The label would state this.

2) Use Directions

Before fumigation all doors and leaks in the vault would be sealed. All persons not involved with the fumigation would be vacated from the building. This requirement would appear on the label.

3) Reentry Period

Following the treatment period, a full-face, black canister respirator would be required to be worn during reentry. All doors and vents in the treatment area and connected buildings would be opened at this time. Premises would be aerated 24 hours or until the EDB air level is less than 0.4 ppm increased by an IR detector, before reentry is allowed. The label and posted warning signs would contain this information.

8. Additional Requirements for Fumigation of Subterranean and Drywood Termites

a. Use Restrictions for Reducing Applicator and Reentry Exposure

1) Certified Applicators

Fumigation would be carried out only by certified commercial applicators.

2) Protective Clothing

EDB-resistant gloves (butyl rubber), boot covers and apron (butyl rubber, nitrile, or polyethylene) would be required at all times. The label would state this.

3) Use Directions for Drywood Termites

Persons not involved with the fumigation would be required to be vacated from premises. Holes of size and spacing specified by the registrant should be drilled and the recommended dosage of EDB injected into these holes using a calibrated syringe or like device. The label would state these requirements.

4) Use Directions for Subterranean Termites

Persons not involved with the fumigation would be vacated from premises before fumigation and subsequent aeration. Use would not be permitted under slabs which contain air ducts, electrical conduits, or the like. Recommended dosage would be injected through holes drilled in concrete slabs which support infested structures. All holes would be plugged temporarily to prevent the escape of EDB during treatment, and would be sealed permanently immediately after treatment. The label would state these requirements.

5) Reentry Period

During and after fumigation all doors, windows and vents in the treatment area and connected buildings would be opened. Premises would be aerated 24 hours or until EDB air levels are below 0.4 ppm before reentry would be permitted. The label and posted signs would contain this information.

9. Additional Restrictions for Fumigation of Bark Beetle

a. Use Restrictions for Reducing Applicator and Reentry Exposure

1) Protective Clothing

EDB-resistant gloves (butyl rubber), boot covers and apron (butyl rubber, nitrile or polyethylene) would be required at all times. The label will state this.

2) Use Directions

EDB would only be applied to infested, felled logs by spraying recommended dosage onto stacked logs, immediately covering the stack with heavy plastic, and sealing this cover with sand snakes. Signs would be posted on the treated stacks stating when the cover could be removed. Spraying logs in the open without an approved covering would be prohibited.

10. Additional Restrictions for Fumigation of Japanese Beetle Under USDA Quarantine Program

a. Restrictions for Reducing Applicator and Reentry Exposure

Under the authority of the Organic Act (7 U.S.C. 147a), the APHIS program of USDA has established a Japanese beetle quarantine program which requires fumigation of certain regulated articles (such as infested plants, grasses or soil) before they can be shipped out of a quarantined area. The APHIS Japanese Beetle Program Manual specifies the approved pesticides and treatment methods. A review of this manual indicates that it could be revised to include the aforementioned minimal use requirements. Further, a review of the two currently registered labels for this use (registration numbers 1681-6 and 3743-263) shows that these labels could be upgraded to describe all the use restrictions and directions for this use pattern. Following are the additional use restrictions or revisions in the APHIS Manual developed by the EPA for each regulated article:

1) Grass Sod

Treated sod would be required to be covered with a heavy plastic or tarp during the treatment period to ensure an efficacious treatment and to minimize air exposures. The tarp would be required to be aired before re-use.

2) Bareroot Plants

The proper method for disposing of the used EDB-water mixture would be specified.

3) Balled or Containerized Plants

The "enclosed place" into which plants are placed after treatment would be posted with signs indicating the minimal reentry information described previously. Proper disposal methods would be described.

4) Potting and Bench Soil

Soil would be covered with plastic or heavy tarp for the duration of the treatment period.

5) Beds and Other Uses

Soil would be covered with plastic or heavy tarp for the duration of the treatment period.

6) For All Above Uses

The APHIS Manual states for balled or containerized plants that treatment is approved only when beetle grubs (larvae) are present. This requirement would be imposed for all regulated articles to avoid unnecessary applications.

V. SELECTION OF REGULATORY OPTIONS

A. Introduction

The purpose of this chapter is to determine the most appropriate regulatory options the Agency should propose for each registered use of EDB. To accomplish this, the risks to human health and the environment for each registered use are systematically compared with the benefits which result from that registered use. If this comparison demonstrates that "unreasonable adverse effects" to man or the environment exist for particular uses, then specific regulatory options are developed to reduce the risks for each of those uses. The Agency then evaluates the extent to which these regulatory options will change the risks and benefits of each use of EDB. Finally, by comparing the changes in the risks and benefits the Agency selects and proposes the most appropriate regulatory measure for each use of EDB.

In previous chapters of this document, the Agency has evaluated both the risks and the benefits which exist as a result of the currently registered use practices of EDB. In addition, the Agency has summarized the regulatory options which are available under FIFRA.

As discussed in Chapter II of this document, the Agency has examined all of the available health studies on EDB. These studies include investigations of possible carcinogenicity, mutagenicity, and reproductive disorders. After a careful review and evaluation of these studies, qualified Agency scientists and outside consultants have reached several conclusions regarding the possible hazards which may result from exposure to EDB.

Based on the accumulation of evidence, the Agency considers EDB to be a potent animal carcinogen and a probable human carcinogen. Because the pesticidal uses of EDB result in human exposure during application, through contamination of some foods during application, and during transport of treated commodities, the Agency concludes that EDB poses a risk of cancer to humans. The Agency also concludes that EDB causes reproductive disorders in bulls, rats and chickens, suggesting that repeated exposure to EDB may cause reproductive disorders in humans. Finally, the Agency concludes that adequate multitest evidence exists to demonstrate that EDB also causes mutagenic effects in several organisms. This evidence indicates that exposure to EDB poses a potential risk of genetic damage to man. Collectively, these three conclusions confirm qualitatively that human exposure to EDB poses substantial risks to the public health.

The Agency has quantitatively estimated the cancer risks to the public which exist due to current registered use practices. Animal toxicity data and the human exposure estimates were used to evaluate the lifetime probability of EDB-induced cancers to the general population and to occupationally-exposed workers. Probability estimates, based on total dietary exposure resulting from residues persisting in EDB-fumigated commodities, range from approximately 10^{-6} to 10^{-4}. Applicator risk estimates range from 10^{-5} for soil fumigation operators to 0.4 for some persons involved in the fumigation ofcitrus.

The Agency has determined that human exposures to EDB also pose a risk of mutagenic effects and reproductive disorders to exposed individuals. The Agency has not quantitified the risk of mutagenic damage to exposed individuals, but has concluded that these risks exist and must be taken into consideration in determining the most appropriate regulatory actions. Based on the NOEL for reproductive disorders observed in rats (as well as the reproductive disorders observed in bulls) and based on the applicator exposure levels, the Agency has also determined that an adequate margin of safety does not exist. Although the Agency does not plan to perform a quantitative risk assessment for reproductive disorders, it will propose regulatory options that should provide an adequate margin of safety by significantly reducing exposure.

Benefits resulting from the use of EDB, summarized in Chapter 4 of this document, are estimated to be approximately 60 million dollars per year. Of the estimated fifteen million pounds of EDB used annually, over eleven million pounds are used for soil fumigation. However, the largest economic benefits of EDB use do not result from its use as a soil fumigant but result from a significantly lower volume use - the USDA APHIS quarantine program. This program requires that in certain geographic areas citrus and certain other commodities be fumigated with EDB prior to transport in order to prevent the spread of fruit flies into geographic regions where they are not established. While this program accounts for less than one percent of the annual EDB usage, it can account for over 30% of the benefits of EDB, an estimated 24 million dollars annually.

It is for reasons such as this that each major use category is systematically analyzed in the following pages using these and significant factors. For a given use category, the risks and benefits are reviewed and the data gaps identified. The significant human health risks are then weighed against the corresponding benefits and a judgment is made as to whether or not the risks outweighed the benefits. If regulatory actions are required to reduce these risks, an analysis is then made of the extent to which each available regulatory action might reduce the risks. The most reasonable regulatory measure is identified and proposed for that use category.

B. Fumigation of Stored Grains

1. Summary of Risks and Benefits

The Agency has determined that the general population, grain fumigation applicators, and individuals handling EDB-fumigated grains are at risk to health hazards as a result of exposure to EDB. The risks include cancer, mutagenic damage, and reproductive disorders. As discussed in Chapter II, the Agency has concluded that residues of EDB persist in flour, baked breads, and other baked flour products made from wheat fumigated with EDB. The range of expected residues which the Agency has determined occur in bread baked from this flour vary from 0.07 ppb to 38 ppb. Based on these residue levels, the Agency has estimated that the lifetime risks of EDB-induced cancer to the average U.S. citizen on a typical diet vary from approximately 10^{-6} to 10^{-4} for this registered use. Although the Agency has not quantitatively estimated the public's dietary risk of mutagenic damage and reproductive disorders, it has concluded that these combined risks warrant consideration of additional regulatory actions.

The Agency has no monitoring data on exposure to EDB for individuals who fumigate stored grains. However, based on available exposure data from similar use practices for other grain fumigants, the Agency has concluded that grain fumigant applicators are exposed to EDB through dermal contact and the inhalation of EDB vapors. Mixing, loading, use, and storage of EDB-containing grain fumigants can expose applicators and individuals in the immediate vicinity to EDB vapors. Commonly occurring spills of these fumigants on skin or clothing also result in dermal contact for applicators. As a result of these exposures, about 50,000 to 60,000 applicators and "non-involved" persons are potentially at risk to the health hazards of EDB.

In addition to the above risks, persons involved in the transport or handling of EDB-fumigated grains as they move through commerce (dock workers, grain inspectors, etc.)are potentially at risk to the health hazards of EDB. These risks result in people being exposed to vapors which have slowly dissipated from treated grains and which have been trapped in storage or transport systems. The Agency has no exposure data for this occurrence and has not estimated the number of people exposed in these situations. The Agency has determined that the health risks resulting from these exposures, should be considered in the selection of an appropriate regulatory action for this use.

Bystanders in the immediate area of use or transfer of EDB grain storage fumigants can also be exposed to EDB vapors. The Agency has not evaluated the exposure to these individuals in its quantitative risk estimates because of a lack of needed data. There are no estimates of the number of persons exposed, but the Agency recognizes that such exposure can occur and would be attended by health risks which should be considered in the development of a proposed regulatory position.

The Agency has evaluated the economic benefits of grain fumigation with EDB and has determined that on a national basis there would be no adverse economic impacts if EDB were cancelled; in fact, users would save money by using alternative pesticides. As discussed in Chapter III, EPA has determined that certain available alternative fumigants, if used properly, are more economical and that, on a national basis, farmers would save approximately 0.5 to 2 million dollars by using them. These alternatives, which will be examined in detail later in this section, are aluminum phosphide and a mixture of carbon tetrachloride and carbon disulfide.

These savings tend to obscure the fact that under certain conditions there are advantages in using EDB. Grain storage facilities, which allow fumigant vapors to dissipate easily because the storage facility is not well-sealed, may be better suited to EDB due to its characteristic persistence. However, the Agency has concluded that, in most cases, the alternatives will be more economical.

If EDB were cancelled, the most likely substitutes would be a mixture of carbon tetrachloride and carbon disulfide at on-farm storage facilities, and aluminium phosphide at off-farm storage centers. Because on-farm and off-farm facilities vary widely in airtightness, the substitutes also vary -- the tighter the facility, the more likely it is that the substitute would be aluminum phosphide. This grain fumigant is less costly but requires a well-sealed storage facility and a longer exposure period to be effective.

2. Risk/Benefit Analysis

Based on the above risk and benefit information, the Agency has concluded that the risks exceed the benefits for EDB fumigation of stored grains. Thus, risks of unreasonable adverse effects to the public health exist and will continue to exist unless regulatory actions are implemented to reduce oreliminate these risks. This conclusion is based mainly on potential dietary risks and the estimated negative economic benefits. It is supported by the potential health risks to grain fumigant applicators, individuals who handle EDB-fumigated grains, and non-applicators who may be exposed to EDB vapors during storage, transfer, or use.

Accordingly, the Agency has evaluated several regulatory options which might reduce these risks. Table 29 displays the impacts which each regulatory option would have on human health risks resulting from exposures to EDB, the health risks of the likely substitutes for this use of EDB, and the expected economic impacts.

All actions short of immediate cancellation would result in continued dietary risks. Options 2 and 3, "Classify for Restricted Use" and "Restricted Use Classification Plus Changes in the Terms and Conditions of Registration" would result in some reduction in applicator and dietary risks because some EDB users might voluntarily switch to alternatives. However, only immediate cancellation would eliminate all EDB dietary and inhalation risks. Because unreasonable dietary effects continue to exist for all options less restrictive than immediate cancellation, the Agency has concluded that immediate cancellation of this registered use of EDB is necessary. Immediate cancellation is further supported by the availability of alternative fumigants which are less expensive and which the Agency considers will pose less risk to applicators and the public when compared to EDB.

To reach determinations about the risks of the alternatives, available health effects-related studies on these chemicals were reviewed with these results:

Use of aluminum phosphide in not expected to result in unreasonable risks to applicators or the general public. Aluminum phosphide has an established tolerance for many food products including grains. This chemical rapidly reacts with water in air resulting in the release of phosphine gas and a residue of aluminum hydroxide. It is this gas which actually destroys insect infestation. Because phosphine is a highly reactive and fugitive gas, residues on commodities or treated materials are not expected. Phosphine is acutely toxic and poses a risk to unprotected applicators. If the precautions specified on the label are followed explicity, applicators, should be adequately protected. Aluminum hydroxide, a common ingredient in antacids, does not appear to pose a health hazard, as determined by an FDA review of toxicology data.

Carbon disulfide (CS_2) is an acutely toxic, highly flammable and penetrative liquid. It is formulated in a mixture with carbon tetrachloride and other fumigants to reduce its flammability. Adequate toxicological data are not available to determine if carbon disulfide poses chronic hazards to humans. Likewise, no studies have been conducted to determine whether residues of CS_2 might occur in food. Though CS_2 is exempt from tolerances for grains because residues were not expected to occur in food or feed, the Agency considers it prudent and is initiating a study to determine if any residues of CS_2 can be detected in grain or flour. If residues are found, registrants of CS_2 may be required to submit chronic feeding studies.

The third major alternative pesticide is carbon tetrachloride. Now under RPAR review, CCl_4 has been presumed to present a risk to humans of cancer, chronic liver effects and chronic kidney effects. CCl_4 is also suspected of inducing mutagenic and teratogenic effects in laboratory tests.

Table 29 Impacts of Regulatory Options on Stored Grains

Regulatory Option	EDB Human Health Risks Exposure Route	 Risks	Risk of Substitutes Human/Environmental	Economic Impacts Users	 Consumers	Comments
1. Continued Registration	Inhalation, Dermal Dietary	See Tables 18 and 20 for cancer risks and discussion in Chapter II for other possible risks	Not applicable	None	None	Unreasonable dietary, dermal and inhalation risks continue
2. Classify for Restricted Use and require: A. Protective Equipment B. Reentry Period C. Placarding	Many users will voluntarily switch to alternatives rather than follow this restriction. Some users will continue with EDB.	Reduced risks to applicators. Dietary risks are reduced only if users switch to alternative fumigants.	Carbon Disulfide has data gap for chronic hazard (data to be required if EPA study finds residues in bread). Aluminum phosphide is acutely toxic but presents no particular hazard. Carbon tetrachloride is carcinogenic but exposure to this would not increase.	Not Analyzed	None	Unreasonable dietary risk to consumers and dermal and inhalation risks to non-applicators continue.
3. Option 2 plus any of the following changes in terms and conditions of registration A. Holding period B. Cancel on-farm EDB use C. Cancel off-farm EDB use D. Prohibit treated grain from going to human consumption	Same as Option 1.	Dietary risks may be reduced, but monitoring and enforcing these terms and conditions would be difficult.	Same as Option 2 Dietary risks may be reduced, but monitoring and enforcing these terms and conditions would be difficult.	Unknown. (Analysis was not done due to questions of enforceability).	None	Dietary risks may not be reduced to acceptable levels because the Agency is not confident that changes in terms and conditions would be followed or enforceable
4. Cancel after 5 years and implement Option 3 in the interim.	Same as Option 1	Dietary and inhalation risks would continue for 5 yrs.	Not applicable	None	None	Would allow existing stocks to be used.
5. Cancel immediately	None	EDB risks eliminated	Same as Option 2	Users will save $0.5 to $2.26 million.	Negligible	Additional residue data being developed for substitutes by the Agency. Chronic exposure studies may be required for CS_2 if there is exposure.

However, the cancellation of EDB is not expected to increase the health risks of CCl_4, because exposures to CCl_4 are not expected. The EDB mixture which is applied to grain, is formulated with CCl_4 and other liquid fumigants. The concentration of CCl_4 in these mixtures usually ranges between 70% and 90%. If EDB is cancelled, the predominant substitute is a mixture of 80% CCl_4 and 20% CS_2. Thus, roughly the same amount of CCl_4 is contained in the substitute mixtures. As a result, exposure to CCl_4 would not be expected to increase.

In summary, from the available information, the Agency concludes that, aluminum phosphide and carbon disulfide used according to labeled safety precautions, will not pose the range or magnitude of adverse health effects to users and to the public that the use of EDB poses. Once cancellation is effective, the Agency will initiate action to revoke the current exemption for grain from tolerances for EDB.

The Agency must act to reduce the unreasonable risks posed by EDB. Cancellation is the most effective and viable option in light of the high risks of EDB and the fact that the alternative fumigants, which are less expensive, are just as efficacious and will not pose the range or magnitude of adverse health effects to users or the public as demonstrated for EDB. This decision is enhanced by the recent development of carbon dioxide, nitrogen and combustion product gas as effective means of controlling pests in stored grain. If these gasous insecticides are exempted from tolerances and prove to be technically and economically feasible, they will be additional alternatives to EDB.

C. QUARANTINE FUMIGATION

1. Summary of Risks and Benefits

As discussed in Chapter II, over 99% of the EDB used for quarantine purposes in 1977 was applied to citrus and tropical fruits (85,000 lbs.) and the remaining amount (300 lbs.) was applied to miscellaneous fruits and vegetables. The Agency has determined that both the risks to human health and the economic benefits which result from this registered use may be substantial. The Agency is concerned that the estimated benefits may substantially overstate the economic value which results from current use practices for this registration. This issue and the fact that there are currently no registered chemical or approved nonchemical alternatives for this use have complicated the Agency's decision as to what regulatory action to propose for the use of EDB in quarantine fumigation.

In Chapter II, the Agency established that significant human health risks are present as a result of current EDB use practices in quarantine fumigation programs. These include risks to the health of the general public through exposures to EDB residues persisting in treated commodities, and health risks to occupationally-exposed individuals, including those working at or around EDB fumigation centers and those working in warehouses where fumigated commodities are temporarily stored. The health risks are cancer, mutagenic effects, and reproductive disorders.

The Agency has quantitatively estimated the lifetime cancer risks to the general public and has established that significant cancer risks result from current practices at quarantine fumigation centers. The residue estimates forming the basis of estimated risks are supported by chemical analyses of EDB residues which were found in commodities obtained from retail grocery stores.

As discussed in Chapter II, the Agency has determined that the lifetime risks of EDB-induced cancer to the general public range from approximately 10^{-4} for citrus to 10^{-5} for tropical fruits.

The Agency has also determined the lifetime risks of cancer for persons occupationally exposed, including fumigation center employees, truckers involved in the transport of fumigated commodities, and persons involved with the movement and handling of fumigated commodities into and out of warehouses. As discussed in Chapter II, the Agency has estimated the cancer risks to fumigation center employees to vary from approximately 10^{-3} to 10^{-2}, to warehouse workers from approximately 0.1 to 0.4, to outdoor operators of approximately 10^{-3}, and to truckers of approximately 10^{-3}. These cancer risks are among the highest risks the Agency has ever confronted.

In addition to these quantified risks, the Agency has also concluded that adequate evidence exists to demonstrate that EDB causes mutagenic effects in several organisms and reproductive disorders in exposed animals. Though the numerical range of the risks of these health hazards is not available, the Agency has concluded qualitatively that humans exposed to EDB are also at risk to genetic damage and reproductive disorders. These additional risks, together with the cancer risks, demonstrate that the use of EDB in APHIS quarantine programs poses unusually high health hazards to the general public and to occupationally exposed workers.

The benefits resulting from this use of EDB, discussed in Chapter III, may amount to as much as 25 million dollars annually. This estimate is based largely on the assumption that if this registration were cancelled, the grapefruit export market to Japan would be eliminated, resulting in a loss to Florida growers of about 29 million dollars in revenue. However, this loss would be partially offset by an increase in the value of domestically produced mangoes and papayas, and also by the decrease in treatment costs.

It should be noted, however, that the estimated benefits from this use may be substantially overstated because they are based on the assumption that the grapefruit export market to Japan will be lost if this registered use is cancelled. The Agency recognizes that this export market was established on an understanding between the U.S. and Japan that grapefruits and certain other citrus destined for Japan from Florida will be treated with EDB prior to shipment as a quarantine measure against the spread of fruit flies. The loss of this export market rests on the assumption that if this registered use of EDB were cancelled, the Japanese would no longer accept Florida's citrus because it had not previously been treated with EDB. One possible option is to cancel the use of EDB on crops destined for consumption in the U.S., and allow its continued use on crops designated for export to Japan. However, it may happen that the Japanese government will decide that EDB fumigation is unacceptable and will not allow EDB-treated grapefruit and citrus to be imported. Thus, the actual impacts of cancelling this use of EDB depend on whether or not the Japanese will continue to require EDB treatments.

The underlying assumption that there are no viable alternatives to EDB for this use also has direct bearing on the estimated economic impact of cancelling EDB. There are no registered chemical alternatives for this use of EDB, nor are any approved non-chemical treatment methods presently available. Heat vaporization cooks the fruit, giving it an "off" taste; furthermore, there are no known available commercial vapor-heat chambers. Cold treatment damages grapefruit and other citrus; it cannot be used on mangoes or papaya, and causes a loss of about 10 percent in other miscellaneous fruits and vegetables.

However, gamma irradiation, a non-chemical method, is a promising substitute for EDB post-harvest fumigation. In many countries, irradiating foods with gamma radiation has been shown to be an economical, effective and safe method for eliminating pests from fresh foods. A number of foreign countries, including Japan, have approved and are using gamma radiation for food preservation and/or insect disinfestation. Appendix 2 lists the status by country of the acceptability of food irradiation. In the U.S., irradiation is subject to approval of the Food and Drug Administration (FDA) under the authority of the Food, Drug and Cosmetic Act. In fact FDA has already approved its use on for use on white potatoes and wheat (21 CFR 179.21). The Agency has had numerous meetings with both FDA staff and food irradiation experts to determine if irradiation of citrus should be considered as a potential substitute for this use of EDB. As a result, the Agency has concluded that irradiation is a potential substitute and should be a factor in developing a regulatory decision. This conclusion is based both on the Agency's recent discussions (Williams, 1980a and b; Savinski 1980; Welt, 1980a and b; Beeder, 1980a) and on recommendations made by the Interdepartmental Committee on Radiation Preservation of Food (ICRPF) in their report entitled, "Food Irradiation in the United States" (December, 1978).

Thus, the impact of cancellation of this use of EDB also depends on FDA approval of the use of gamma radiation as an insect disinfestation method for citrus and tropical fruits, as well as on Japan's acceptance of this substitute method. If the FDA approves and the Japanese accept irradiation of citrus as an alternative to EDB, then the current estimates of the benefits for this use of EDB may be significantly reduced. However, the Agency has not thoroughly studied the economic impacts of the use of irradiation.

2. Risk/Benefit Analysis

The Agency has evaluated the risks to human health and the economic benefits which result from current use practices and has concluded that this use causes unreasonable adverse effects to humans. Regulatory options available to the Agency to reduce these risks are listed in Table 30. This table shows the expected changes in risks and benefits which result from the implementation of each regulatory option.

Option 1, continued registration, would result in the indefinite continuation of unreasonable adverse effects both to the general population from dietary exposure and to workers applying EDB or handling treated fruit. The benefits of this use of EDB, approximately 25 million dollars annually, would remain unchanged.

Under Option 2, the Agency would impose restrictions to reduce risks for truckers, employees at fumigation centers and warehouse workers. Various means of reducing dietary exposure to the general population were explored in Chapter IV, however, none were considered to be effective or practical. Consequently, this option would only reduce risks to persons occupationally exposed to EDB. Risks to the general public would continue indefinitely because this option would have no impact on residues in citrus and tropical fruits. The benefits resulting from implementation of this option would remain essentially the same as in Option 1, because costs to impose the restrictions are small, about 13,000 per facility. (See Table 30).

Option 3 would permit EDB use to continue until a specific date. During the period of continued use, the restrictions specified in Option 2 would be imposed. Because there are currently no effective registered alternatives to EDB, selection of this option would allow for the development and implementation of alternative safer methods for use on quarantined commodities.

With implementation of this option the risks and benefits would change as the restrictions imposed change. The immediate impacts on risks and benefits, which would last until cancellation became effective, would be the same as those under Option 2 (i.e., reduced risks to applicators, continued high dietary risks to the general public, and essentially unchanged high economic benefits). Once cancellation became effective all EDB health risks would be eliminated, both to exposed applicators and to the general public from dietary exposure to EDB residues in treated commodities. The economic impact of cancellation, if gamma irradiation or another alternative became available, would be the capital investment costs, amortized over an appropriate period of time, plus the operating costs, minus the costs of treatment with EDB. The Agency has not examined these costs in detail, but has obtained some preliminary estimates of the operating costs for an irradiation facility with the capacity for effectively eliminating fruit flies on about 4 million pounds of packaged citrus per day (Welt, 1980a). At a minimum dosage level of 25 Krad, not to exceed 50 Krad, the estimated cost of processing is between $52 and $90 per 40,000 lbs of citrus. This cost estimate is based on 100,000 cases of grapefruit containing 40 lbs per case. Costs of the implementation and use of gamma radiation as a pesticide have been studied in great detail in a report entitled "Food Irradiation in the United States", prepared by the Interdepartmental Committee on Radiation Preservation of Food (December, 1980). Conclusions from this report were that "Use of chemical pesticides such as ethylene oxide, methyl bromide and ethylene dibromide could be reduced or eliminated."

Option 4 is immediate cancellation of the use of EDB to treat commodities destined for consumption in the U.S., while permitting its use to continue for fumigation of commodities destined for export, and requiring the same restrictions as would be imposed by Option 2 to reduce applicator risks. This option has three possible outcomes. The impact on risks and benefits depends on the possible outcomes. Under this option, dietary risks to the U.S. public would be eliminated and the risks to fumigation center and warehouse employees would be reduced. The economic impacts of this option could be highly variable depending on which outcome results. One outcome is that the Japanese government could continue to accept imported citrus which as been treated. If this outcome were to occur, the reductions in benefits could be small under the first outcome, amounting to an estimated $1.6 million. A second outcome of Option 4 is that the Japanese might decide to refuse EDB-treated citrus, in which case the economic loss to growers and the U.S. balance of trade would be large ($25 million and $27 million, respectively). A third possible outcome is that the U.S. could substitute gamma irradiation for EDB and still retain the Japanese export market. In this case, the economic impact on growers would be a change in treatment costs which the Agency has not evaluated.

Option 5 is immediate cancellation of all EDB used for post-harvest fumigation. This option would have significant impacts on both the risks and benefits of EDB. All risks of EDB would be immediately eliminated. Because the export market to Japan would be lost, the Agency estimates that citrus growers would lose $25 million in revenue losses and that there would be a net $18.4 million loss in the U.S. balance of trade.

Upon evaluation of the impacts each regulatory option has on the risks and benefits, the Agency has concluded that Options 1, 2 and 4 should be eliminated from further consideration and that only Options 3 and 5 should be examined in more detail. The reasons for eliminating the three options are as follows:

Option 1--continued unrestricted use--would result in the continuation of unreasonable adverse health effects to the general public, to the occupationally exposed worker including fumigation center employees, warehouse workers, and truckers, and to those individuals living around fumigation centers.

Option 2--classifying for restricted use and requiring fumigation center and warehouse modifications--would reduce the risks to workers through the implementation of these measures. The benefits would remain essentially unchanged. However, risks of unreasonable adverse effects to the U.S. population through dietary exposures to EDB would continue.

Option 4--immediately cancelling the use of EDB to fumigate commodities destined for consumption by the U.S. public, while retaining its use to fumigate commodities intended for export to foreign markets and imposing measures to reduce U.S. worker risks--would eliminate all dietary risks to the U.S. public and would reduce U.S. workers' risks. However, this regulatory option would announce to the international community that the Agency has not attempted to reduce the potential dietary residues and health risks which may be faced by countries importing U.S. treated commodities. The Agency views this option as a poor approach to the solution of an international environmental problem. The Agency rejects this option as an acceptable alternative.

The Agency has conducted an intensive comparative evaluation of the risks and benefits resulting from the implementation of Options 3 and 5.

Option 3--cancellation on a specific date of all uses of EDB to fumigate quarantined commodities, and in the interim requiring measures to reduce worker exposure--would allow the benefits of this use to continue until the date when cancellation becomes effective. The EDB health risks to workers would be reduced in the interim, while the benefits of approximately $25 million annually in revenue would be reduced only slightly by the costs to install worker exposure reduction measures. In addition, positive balance of trade payments of about $18 million annually would be retained. With no effective approved chemical or nonchemical alternatives to EDB currently available for this use, the interim period would allow for the replacement of EDB with a safer alternative.

However, until cancellation becomes effective, residues of EDB would continue to occur in fumigated food commodities, and the U.S. public would be at risk to unreasonable adverse effects resulting from dietary exposures to these commodities. Persons in countries that import commodities treated in the U.S. would be also potentially at risk to adverse health effects. The Agency has determined that the lifetime probability (70 yr) of EDB-induced cancer to

Table 30. Impacts of Regulatory Options on Post-Harvest Fumigation of Citrus, Tropical Fruits, and Vegetables

Regulatory Option	EDB Human Health Risks		Risks of Substitutes	Economic Impacts		Comments
	Exposure Route	Risks	Human/Environmental	Users	Consumers	
1. Continued Registration	Inhalation Dietary	See Tables 18 & 20 for cancer risks. See discussion in Chapter 5 for other possible risks.	Not Applicable	None	None	Unreasonable dietary and inhalation risks continue.
2. Classify for Restricted Use and require fumigation center and warehouse modification (see Chapter 4 for list of restrictions)	Same as Option 1	Reduced fumigation center and warehouse employee inhalation risks; dietary risks unchanged.	Not Applicable	$500.00 per each fumigation chamber $13,000 per fumigation center for monitoring and analytical devices. 1/	Minimal	Unreasonable dietary risks continue.
3. Option #2, plus cancel after a specific time period.	Same as Option 1	Same risks as for Option #2 except that all risks are eliminated after selected date when cancellation would become effective	Not Applicable	Option #2 plus unknown but probably moderate costs for installation of gamma irradiators or other alternative treatment methods which become available	Minimal	This option could allow time for alternatives to be developed and registered.

1 Per chamber cost includes expenses for installation of a closed EDB delivery system, ventilation equipment and safety devices (based on personal communication, J. Whitesides to J. Panetta 7/16/80).

Table 30. Impacts of Regulatory Options for Post-Harvest
(Cont.) Fumigation of Citrus, Tropical Fruits, and Vegetables

Regulatory Option	EDB Human Health Risks		Risks of Substitutes	Economic Impacts		Comments
	Exposure Route	Risks	Human/Environmental	Users	Consumers	
4. Immediately cancel use of EDB on crops consumed in the U.S., but allow continued use on exported commodities, with Option # 2 restrictions imposed.						
Possible Outcomes:						
A. Export market to Japan is retained because EDB-treated citrus is acceptable to Japan.	Inhalation	Reduced occupational risk; U.S. public dietary risks eliminated. Risks to Japanese unknown.	Not applicable	$1.6M (cost of using gamma irradiation not included).	Minimal	Assumes Japan will continue to accept EDB treated fruit.
B. Export market to Japan is lost because EDB-treated fruit is unacceptable to Japan.	None	All EDB risks eliminated.	Not applicable	$25M to users. $18M loss in balance of trade.	Consumer prices would be lowered due to excess supply of citrus in the U.S.	Assume citrus previously exported will be absored by U.S. market through price reductions.
C. Export market is retained through the substitution of irradiation. or other alternative treatment method	None	All EDB risks eliminated.	The occupational risks associated with use of irradiation in the U.S. are unknown, but likely to be negligible.	Cost of implementing and using irradiation.	None	Japan is already using irradation for use on some foods; however, radiation could not be adopted immediately in the U.S.

Table 30. Impacts of Regulatory Options for Post-Harvest
(Cont.) Fumigation of Citrus, Tropical Fruits, and Vegetables

Regulatory Option	EDB Human Health Risks Exposure Route	 Risks	Risks of Substitutes Human/Environmental	Economic Impacts Users	 Consumers	Comments
5. Immediately cancel use on both domestic and export crops.						
Possible outcomes:						
A. Export market to Japan is retained because irradiation or other alternative treatment is acceptable to Japan	None	All EDB risks eliminated	Occupational risks of using irradiation in the U.S. are unknown, but likely to be negligible	Same as 4C.	Minimal	Japan and other countries are already using irradiation as a food preservation technique. But irradiation could not be implemented immediately. No protection would be offered against the fruit fly until implementation of irradation.
B. Export market to Japan is lost because irradiation is unacceptable to Japan	None	All EDB risks eliminated	Not Applicable	$25M	Consumer prices would be lowered due to excess supply of citrus in the U.S.	Irradiation will likely not be used. Outcome results same as Option 4, Outcome B.

the average U.S. citizen is in the range of 10^{-4} for citrus and 10^{-5} for tropical fruit. Thus, for example, if the Agency chose 70 years as a date when cancellation of this use would become effective, one person in every 10,000 might incur cancer as a result of EDB residues in citrus, and one in every 100,000 from residues in tropical fruits. In addition to these risks,the public would also be at risk to reproductive disorders and mutagenic effects.

The Agency considers these high levels of risk resulting from lifetime exposure to be unacceptable, even in comparison with the considerable benefits of EDB for this use. To allow the use of EDB to continue for seventy years isunacceptable.

Option 5--would eliminate the risks of EDB entirely, and for this reason it has received serious consideration. Without appropriate alternative treatment methods however, this option would totally eliminate the benefits of EDB for quarantine use.

There is one vital consideration which the Agency has extensively investigated: whether gamma irradiation presents a viable alternative to EDB in the near future. As indicated previously, this method is effective and approved for use in many countries, but has not yet been approved for use in the U.S. The USDA APHIS has been researching this method for a decade, and since 1974 has been attempting to receive approval of its petition to FDA for use of gamma irradiation on mangoes and papays. USDA testing has also shown good results for citrus.

Recently, the EPA has met with the USDA and FDA to determine if USDA's petition for the use of irradiation as an alternative to EDB can be resolved. Based on these discussions FDA has accelerated its review and it appears that FDA could approve the use of gamma irradiation within 18 to 24 months. Based on the Agency's contacts with manufacturers who market irradiation systems, it appears that about 9 months would be required to install such systems (Welt, 1980a).

Based on this factor alone--that irradiation technology can be implemented within about 24 to 36 months--the Agency believes that Option 3 presents the best solution. With this option the dietary risks to the U.S. population would continue for 2 to 2 1/2 years. The estimated cancer risks are based on a 70 year lifetime exposure, the cancer risks associated with this interim period of 2 years would be about 2/70 of that risk, or about 10^{-6} for citrus and 10^{-7} for tropical fruit. In light of the large benefits of EDB that would continue for this period, the Agency finds that these lower risk levels would be acceptable, but only for the 2 to 2 1/2 yr period. Any further continuation of risk would be considered unreasonable. Regarding risks to applicators and warehouse workers, the Agency finds that implementation of the safety measures previously described would significantly reduce the risks to these persons without significantly effecting the economic benefits.

In conclusion, the Agency selects Option 3--phase-out of EDB after no more than 2 1/2 years from now, and immediate implementation of applicator and worker protection measures specified in Chapter IV or other measures to ensure that the EDB air standard of 0.4 ppm is met. A reasonable date for the cancellation to become effective would be July 1, 1983. After that date, no use of EDB will be allowed for post harvest commodity fumigation.

D. SPOT FUMIGATION OF GRAIN MILLING MACHINERY

1. Summary of Risks and Benefits

In Chapters II and III, the Agency evaluated the risks and benefits resulting from spot fumigation of milling machinery and cereal handling equipment. This periodic treatment with EDB of critical spots in grain milling machinery, ducts and conveyors is specifically timed to break the life cycle of invading pests, thus preventing the tremendous increase in pests which could result from the development of a second generation. The Agency has determined that this use of EDB, amounting to 465,000 pounds per year, causes health risks to the general public, mill workers, and fumigators. An investigation of alternatives revealed that the only effective alternative for this use of EDB is general space fumigation of the entire mill.

Recent studies which investigated the potential for residues of EDB to contaminate wheat flour following spot treatment confirm that flour does absorb residues and that they may persist for two weeks following treatment. The amount of EBD which contaminates flour varies greatly and depends on numerous factors including the length of time between spot treatment and wheat processing, the concentration of EDB in incoming wheat, and the construction of the flour mill. The Agency has determined that the average annual dietary burden resulting from this use of EDB ranges from 0.7×10^{-3} to 2.77×10^{-3} mg/kg/yr. The Agency's Carcinogen Assessment Group used these residue levels and estimated that the lifetime cancer risks to the U.S. public range from approximately 10^{-4} to 10^{-5}.

These residue levels and the corresponding dietary cancer risks are viewed by the Agency as upper bound estimates of the actual cancer risks. The estimated residue levels in bread include the assumption that all flour mills use EDB as the method of treatment of milling equipment for pest prevention. The number of mills using this process is unknown, as is the amount of wheat flour processed annually through these mills. In the absence of this information, the Agency has assumed that all mills use EDB.

The Agency has determined that spot treatment fumigators and mill employees are exposed to EDB vapors. These conclusions are based on findings from actual EDB air concentrations measured during and after spot treatment. To estimate the risks to fumigators of EDB-induced cancers, the Agency has considered both typical exposures and potential "worst-case exposures" (involving a fumigator who moved or adjusted his face mask). The estimated lifetime risks range from approximately 10^{-3} to 10^{-1} for applicators and 10^{-2} to 10^{-3} for mill workers.

EDB, used as a spot fumigant in flour mills, also presents potential risksof mutagenic effects and reproductive disorders to the general public, mill workers and fumigators. Although these risks have not been quantified, they must also be considered along with the cancer risks in weighing the risks and benefits of this general use of EDB.

The Agency estimates the economic benefits of spot fumigation to be in the range of 4.6 to 7.5 million dollars annually. These benefits are based on the assumption that, if this use of EDB were cancelled, the alternative would be general space fumigation with methyl bromide or aluminum phosphide. The costs are estimated to vary from 13 to 21 thousand dollars per year for individual wheat and rye mills, and from 8 to 14 thousand dollars per year for dry corn mills. The resulting annual consumer impacts would vary from an estimated 1.6 to 2.8 cents per capita per year for four general space fumigations, to 2.8 cents if five such fumigations are required.

The Agency has reviewed available data on the two substitute chemicals, methyl bromide and phosphine, the active ingredient and degradation product of aluminum phosphide. Unlike EDB, which is a liquid at room temperature (b.p. 131°C), the alternatives (methyl bromide and phosphine, the active ingredient of aluminum phosphide) are gases and would not be expected to leave significant residues on treated surfaces and commodities. Both phosphine and methyl bromide are acutely toxic, posing health hazards to unprotected applicators. However, available toxicology information and consideration of the physical properties of these chemicals lead the Agency to conclude that because of the low expected residue level, neither would cause unreasonable adverse chronic effects. Methyl bromide is known to cause mutations in some laboratory test systems. Application and ventilation practices which protect applicators from acute hazards should also provide significant protection to guard against the potential mutagenic hazards of methyl bromide.

2. Risk/Benefit Analysis

Based on the above risk and benefit information, the Agency has determined that the risks of adverse health effects exceed the economic benefits which result from the use of EDB in spot fumigation of grain mills. Therefore, unreasonable adverse effects to the public health exist and will continue to exist unless the Agency adopts regulatory options to reduce them.

This determination has led the Agency to evaluate several regulatory options which might reduce these risks. Table 31 presents the impact of each option on the risks and benefits of spot fumigation.

Option 1, continued registration, would result in continued risks of adverse health effects to the general population through dietary exposure, and to applicators and flour mill employees through dermal and inhalation exposures.

Option 2, imposing certain use restrictions see details in Chapter IV) would reduce applicator and general mill worker inhalation exposures to the NIOSH recommended level of 0.4 ppm. Applicator dermal exposures would also be reduced. However, this option would not reduce the residues of EDB which contaminate flour processed through grain milling equipment fumigated with EDB.

The intent of Option 3 is to achieve the same exposure reductions as Option 2, and also to lower the EDB-contamination of flour. By requiring that the first batch of flour, produced after a mill has been fumigated, be discarded, a portion of the EDB residues would be eliminated. However,the available information is not adequate to determine the degree of reductionin residues that might be achieved by this measure. Further, it would be difficult to enforce such a restriction or to expect a high degree of voluntarycompliance. Consequently, Option 3 would not likely result in a significantreduction of the dietary residues of EDB from spot fumigation.

The impacts of Option 4, cancelling use after 5 years and restricting use for the interim period, is the same as Option 3 until after the 5th year, at which time the impacts would be the same as Option 5, i.e., cancellation. The purpose of this option would be to allow time for flour mills to upgrade their facilities to use methyl bromide or aluminium phosphide.

Table 31 Impacts of Regulatory Options for Spot Fumigation

Regulatory Options	EDB Human Health Risks		Risk of Substitutes		Economic Impact		Comments
	Exposure Route	Risks	Human	Environmental	Users	Consumers	
1. Continued Registration	Dietary Inhalation and Dermal	See Tables 18 and 20 for cancer risks and discussion in Part II for other possible risks.	Not Applicable		None	None	
2. Classify for Restricted Use; impose use restrictions listed in Part IV	Same as Option 1	Dietary Risks continue. Reductions in applicator and non-applicator risks.	Not Applicable		Respirators and clothing cost about $100. Label and reentry impacts are negligible.	None	Applicators would probably comply with restrictions.
3. Option 2 human consumption of flour milled during the first several hours after EDB-treatment	Same as Option 1	Reduced applicator and non-applicator risks. Dietary risks should be reduced but the amount of reduction is not known.	Not Applicable		Cost of discarding flour was not analyzed, but is probably minor.	Negligible	Flour mills might not comply with the holding restriction and enforcement would be difficult.
4. Cancel after 5 years and impose Option 3 for the interim	Same as Option 1	Risks same as in Option 3 for 5 years; no risks after 5 years.	After 5 years, the risks of alternatives are the same as in Option 5.		None	None	During the 5 year period, some mills could modify their facilities for use of methyl bromide or aluminum phosphide
5. Cancel Immediately	No Exposures	All EDB risks eliminated	Aluminum phosphide (AP) and methyl bromide (MB) are acutely toxic MB is a suspect mutagen		$5.1-$6.4M per year for 298 wheat and rye mills; $1.3M/yr. for 93 corn mills. Total max. impact = $7.7 M/yr	1.6 to 2.8 cents per capita	

Immediate cancellation, Option 5, would force EDB users to switch immediately to alternative fumigants at a total increased treatment cost of $7,700,000 per year for all 391 grain mills, or 2.8 cents per consumer. While this is a "worst-case" estimate (because it assumes all mills now use EDB), the potential cost of upgrading some mills to allow maximum effectiveness from space fumigation has not been included. In any event, this option would eliminate the risks of EDB and would result in use of apparently safer substitute fumigants.

As the data presented in Table 31 demonstrate, any action short of immediate cancellation will result in continued dietary risks. If the Agency were to classify EDB for restricted use, or amend the terms and conditions of registration, some users may continue to apply EDB rather than switch to alternatives. Although occupational risks would be reduced, this option would not result in a reduction in the risks to the general public resulting from dietary exposure.

In conclusion, the Agency believes that the health risks of EDB are serious and unacceptable when considered with the benefits, and will only be reduced through immediate cancellation. Cancellation will not result in unreasonable economic costs to grain mills or consumers. There are alternative chemical fumigants for this use which the Agency believes will not cause the public and properly protected applicators to be at risk to the range or magnitude of serious adverse health effects that exist with use of EDB.

E. PRE-PLANT SOIL FUMIGATION

1. Summary of Risks and Benefits

The Agency has evaluated the human health risks and economic benefits of the use of EDB as a pre-plant soil fumigant. The health risks of concern are oncogenicity, mutagenicity and reproductive effects. These risks exist for fumigation applicators and other individuals directly involved in application operations, and might exist for the general public potentially exposed to EDB residues in crops grown in fumigated soil.

The maximum hypothetical risks to humans resulting from potential dietary exposure were estimated for the 16 soil-fumigated crops listed in Table 8 of Chapter II. As discussed in Chapter II, no detectable residues of EDB have been found at a level of detection of 0.001 ppm. Although the analytical method used in these tests has not been completely validated, the Agency assumes that residues will not exceed this level. To determine an upper-bound lifetime probability of EDB-induced cancer resulting from dietary exposure, the Agency conservatively assumed that EDB residues are present at this level of detection. Based on the assumption that a maximum of 0.001 ppm EDB is present in each soil-fumigated crop, the maximum lifetime probability of EDB-induced cancer for the general public varies from approximately 10^{-6} to 10^{-5}. However, because actual levels of EDB are probably below 0.001 ppm, the actual cancer risks are also expected be lower than these maximum risk estimates. The Agency has also concluded that if residues do occur, they also pose a potential risk of genetic damage and reproductive disorders to man.

Soil fumigation applicators and those individuals involved in the transfer of soil fumigants are likely to incur inhalation and dermal exposures during EDB soil application and transfer. Soil fumigation operators are exposed to EDB ranging from 0.7 mg/yr for peach crops to between 303.3 and 532.4 mg/yr for pineapples. The Agency used these exposures to estimate that the life time risk of EDB-induced cancer to soil fumigators is in the range of 10^{-5} to 10^{-3}. As discussed in Chapter II, the Agency has also concluded that exposures to EDB may result in hazard of genetic damage and reproductive problems to exposed individuals.

In addition to the potential for residues occurring in crops, the Agency is concerned that EDB might leach into groundwater as a result of current use practices. Although no data are available on the leaching potential of EDB, residues of the soil fumigant dibromochloropropane (DBCP), which has similar use sites and use practices and chemical properties, have been found in ground water. The Agency views this data gap as a significant issue which must be resolved before final regulatory measures can be determined for this use. As a result, the regulatory actions proposed for this use should be considered as interim measures which will be finalized when adequate information is available to evaluate this issue.

The Agency has evaluated the economic impact of cancelling soil fumigation with EDB and has determined that this use has substantial economic benefits. All alternative treatment methods would be more expensive to farmers. Depending on the crop treated, the total increased costs to farmers of using alternative fumigants would vary from $3,500 for citrus to $3,800,000 for vegetables. The total user impacts of cancelling all preplant soil fumigation uses would approach $21,000,000.

Numerous alternative pesticides are available for use as soil fumigants in place of EDB. The major alternatives in most cases are equally as efficacious as EDB. The alternatives for most crops are DD, Telone II and Vorlex. For pineapple uses, DBCP must be used in combination with DD or Telone. There are both substantial health risks as well as a number of data gaps associated with these substitutes, as shown in Table 26. A recent NCI study shows Telone to be oncogenic. DD and Telone have been demonstrated to be mutagenic in laboratory tests. DBCP is currently suspended for all uses except on pineapples due to its oncogenic, mutagenic and reproductive hazards. The remaining alternatives (Vorlex, Vemacur, Mocup, and Dasanit) have data gaps for most chronic effects hazards.

2. Risk/Benefit Analysis

Based on the above risk and benefits information, the Agency has concluded that there are significant health risks to soil fumigation applicators due to exposure to EDB. The risks of cancer, mutagenic effects and reproductive disorders to the occupationally exposed exceed the economic benefits for EDB soil fumigation. Therefore, it is necessary that the Agency consider appropriate regulatory options to reduce these potential "unreasonable adverse effects to the public health." The Agency considers the potential for EDB residues to occur in water supplies and crops grown in fumigated soils to be data gaps which must be resolved. The regulatory measures which are developed below are interim actions intended to reduce the health risks of EDB use as a soil fumigant. When the data gaps are resolved, the Agency will reevaluate this use to determine if additional regulatory measures are needed.

Table 32 identifies three possible regulatory options. They are in order of increasing restriction: continued registration without restrictions, continued registration with restrictions, and cancellation. Changes in the risks and benefits of EDB expected to result from each option are also shown.

Table 32 Impacts of Regulatory Options on Soil Fumigation

Regulatory Options	EDB Human Health Risks Exposure Route	 Risks	Risk of Substitutes Human/Environmental	Economic Users	Impacts Consumers	Comments
1. Continued Registration	Inhalation and Dermal for applicators. Potential dietary and drinking water for the general public.	See Table 18 and 20 for cancer risks and discussion in Chapter 5 for other possible risks.	Not applicable	None	None	Unreasonable applicator health risks continue. Data gaps exist for groundwater contamination and food residues.
2. Continue Registration, but require Applicator Use Restrictions, Set Tolerances for EDB in Food Crops, Require Studies of Leaching Potential and Food Residues	Inhalation and Dermal for applicators. Potential dietary and drinking water. for the general public.	Dermal and inhalation exposure risks reduced	Not applicable	$175.00 to $600.00 per applicator	None	Monitoring and enforcement will be necessary. Monitoring data needed for potential of groundwater and food contamination. EDB tolerances must be established.
3. Immediate Cancellation	All EDB risks eliminated		DD and Telone are oncogenic and suspected mutagens. Vorlex is acutely toxic, but has no chronic effects data.	$3,500 to $3.6M, depending on use-site.	None	All substitutes present potential risks to human health.

Option 1, continued registration without restrictions, would result in unreasonable adverse effects to applicators, as concluded above. Until more definitive data are provided by registrants, the Agency also assumes that risks to the public may result from potential exposure to EDB in food and/or drinking water.

Option 2, continued registration with restrictions, would significantly reduce risks to applicators, but would have no impact on the risk from potential residues in food or drinking water. As a component of this option, the Agency will require a study of the potential of EDB to contaminate food crops grown in EDB-fumigated soils, and laboratory and field studies of the leaching potential of EDB. The food residue study will investigate if residues of EDB in crops grown in EDB-fumigated soils (at maximum application rates) do not exceed the current limit of sensitivity of analytical methodology of .001 ppm. The studies on the leaching potential of EDB will be subject to the Agency's review and evaluation prior to commencement.

Immediate cancellation, Option 3, would result in significant economic costs to growers, but would eliminate all health risks from EDB. Losses to growers would amount to almost 21 million dollars. In addition, if this use were cancelled, users would substitute other soil fumigants which may also pose significant health hazards and have numerous data gaps. If this use were immediately cancelled, the Agency would have no assurance that the net risks to public health would decrease.

The Agency selects Option 2 as the appropriate regulatory option for three reasons: First, this option will establish risk reduction measures which lower applicators' risks at a reasonable cost. The specific use restrictions for the protection of soil fumigation applicators include all those measures specified in Chapter IV: classifying EDB for restricted use by certified applicators only; requiring applicators to wear a NIOSH/MSHA-approved full face black canister respirator during application; establishing a 24-hr post-application period during which any person reentering the treated area must wear a respirator; requiring EDB-resistant (butyl rubber) gloves and boot covers (butyle rubber, nitrile or polyethylene) be worn during mixing and loading of EDB as well as during the maintenance of application equipment; and requiring signs be posted on the treated site to notify readers of the treatment with EDB and bearing further warning information. These restrictions will result in a significant reduction in worker exposure, while maintaining the economic benefits of EDB.

The second reason for selecting Option 2 is that the risks to public health (pending resolution of the data gaps) which might result from the undetected but possible exposure to EDB, are outweighed by the economic benefits. In determining the risk of cancer due to consumption of EDB-fumigated crops, the Agency assumed that a maximum of 0.001 ppm of EDB was present on each crop. The estimate derived from this assumption is presumed to be a worst-case estimate because EDB has not been detected in analytical tests on such crops at a level of detection of 0.001 ppm. To ensure that any EDB residues remain acceptably low (i.e., < .001 ppm), the Agency proposes to establish a tolerance for residues at the level of detection of EDB per se in or on food crops grown in EDB fumigated soils.

The third reason for choosing Option 2 is that it will enable the Agency to resolve the data gaps concerning the potential for EDB to contaminate food crops and/or to leach into water supplies. Until these data are available, it is not possible to estimate quantitatively the risks for these health hazards of EDB. The Agency therefore proposes to use Section 3(c)2(B) of FIFRA to quickly obtain these additional data. When results of these studies are available and have been evaluated, the Agency will reevaluate whether additional regulatory actions are needed for this use.

Following the suspension of DBCP as a preplant for soybean nematode control in 1979, several states have claimed there are no other registered pesticides that are economical or effective against nematodes. Based on the available test results showing EDB to be as efficacious as DBCP, six states applied for temporary permits (e.g., exemptions from FIFRA) to allow this use under section 18(c) of FIFRA. These exemptions were granted with the requirement that numerous restrictions be implemented to reduce exposures to EDB and the associated health risks to applicators. These exemptions were granted for the period beginning April 24, 1980 and ending July 31, 1980. Table 3 lists these restrictions, those applicants who applied for and received exemption, the area and acreage to be covered, target pests, and the EDB products approved for each use.

F. Minor Uses--Beehive Supers, Vault Fumigation, Termite Control, Bark Beetle Control, and Japanese Beetle Control

1. Summary of Risks and Benefits

The Agency has examined the potential human health risks and the economic benefits for four of the five known lower volume uses of EDB. A risk/benefit evaluation of the fifth use--subterranean and drywood termite control--will be deferred until a cluster analysis for all pesticides used for termite control is conducted. The uses which are evaluated in this section include fumigation of stored beehive supers and honeycombs (to control greater wax moth larvae), vault fumigation of stored clothing and furniture (to control various pests), treatment of felled logs (to control bark beetles), and treatment of APHIS quarantined plants, soil and grass sod (to control Japanese beetles). The health risks include cancer, genetic damage, and reproductive disorders.

As discussed in Chapter II, quantitative estimates of the risks are not available for most of these uses. However, as discussed below, an examination of the use practices for each of these uses reveals that applicators are likely to be exposed to EDB during use and that they may be at risk to unreasonable adverse effects.

Vault fumigation involves the pouring of EDB into a heating device, which evaporates the EDB to penetrate items being treated. The formulation used in vault fumigation is 5% EDB and the period for fumigation is generally 16 hours. Thus, vault fumigators can be exposed dermally during the pouring of the formulation into dispensing containers and through inhalation during pouring and when reentering the vaults. The Agency currently has no information on the amount of EDB used annually for vault fumigation, how many of these facilities exist in the U.S., how many vault fumigation employees there are in the U.S., or the levels of EDB to which vault fumigation can be exposed.

No data exist on the exposures of beekeepers to EDB. However, use practices for the fumigation of stored beehive supers suggest that beekeepers may be exposed both through inhalation and dermal contact but less frequently than applicators for all other registered uses of EDB. Because this fumigation procedure is an annual practice among certain beekeepers, exposures only occur once a year when stored hives and supers are treated during the off season.

Generally, one to two tablespoons of 83% EDB formulation are placed on absorbent material which is set on stacked supers; the stack is then covered with plastic sheeting for 24 hours. Both dermal contact and inhalation of vapor can occur during use. But the Agency has no estimate of the air levels of EDB that could result from such use practices, nor of the frequency or quantity of EDB dermal contact which could occur. However, the number of beekeepers who use EDB could be large, because 20,000 lbs. of EDB are estimated to be used annually for fumigation of supers and hives.

A separate but related issue for this use of EDB is the possibility that EDB residues could occur in honey as a result of application to stored honeycombs. As discussed in Chapter II, the Agency has no data on EDB in honey, but views this as a very unlikely possibility. The Agency considers it as a data gap which must be resolved to determine the total health risks which may exist for this use.

No information exists on the EDB air levels to which individuals are exposed during the treatment of felled logs. However, current use practices suggest that both dermal contact and inhalation exposures will likely occur during this use. Generally, a formulation of 23% EDB is applied to felled logs in one of two ways: spraying to the point where runoff of liquid occurs, or spraying at a lower rate to stacks of wood which are subsequently covered under a plastic sheet. Applicators thus may be exposed to EDB dermally and through inhalation of vapors during loading of sprayers as well as during actual use. The use of plastic sheeting appears to offer some protection against inhalation exposure both because it captures vapors and because of the reduced quantity of formulation needed. Though the Agency has estimated that 20,000 lbs. of EDB were used in 1977, enough to treat an estimated 68,000 trees, there is no information on the number of users or the frequency of use.

For fumigation of quarantined plants, soil and grass sod, the Agency has no information on applicator exposures, number of applicators, frequency of use by applicator, or the amount of EDB used for this site. This use is required by 7 CFR 301.48 (APHIS Japanese Beetle Domestic Quarantine Program). Current use practices suggest that users may be exposed both through dermal contact and to inhalation of EDB vapors. For each of these uses, EDB comprises either 2.5% or 20% of the formulation (see Benefits Chapter). For all applications, the formulation is mixed with water and applied in very low concentrations. During the mixing of the formulation with water, users may contact EDB dermally or via inhalation. During application of the diluted solution, exposure of users to EDB will also occur. Because this solution contains very small quantities of EDB, exposures are likely to be very low.

The four minor uses of EDB each have economic benefits. For beehive supers the benefits are considerable, amounting to more than $10 million annually. EDB is more effective than either of the alternatives, paradichlorobenzene (PDB) and carbon dioxide. PDB is generally much more practical to use than CO_2, which requires elaborate monitoring equipment to ensure efficacy. The substitution of PDB would result in increased treatment costs of about $3.7 million annually (approximately 5 cents per super) due to its higher cost and to the additional treatments required. Because the alternatives are not as effective as EDB, the quantity of domestic honey produced would be reduced by an estimated 6 percent annually, resulting in a loss to beekeepers of $6.5 million. A production loss of this magnitude would shift some of the cost impact to the consumer, but the extent of this impact cannot be estimated.

Use of EDB on infested, felled trees to control the pine bark beetle in western states, primarly benefits private land-owners. Although the extent of EDB use does not appreciably affect the value of commercial timber harvests, control of the pine bark beetle on residential lots may prevent tree mortality losses of $1,500 to $3,000 per lot. The use of the alternative endosulfan could actually reduce total costs by as much as $36,000 annually, in spite of the fact that it may not be as effective as EDB. The other alternative, lindane, could reduce treatment costs by up to $16,000 annually. However, because lindane is in RPAR and is recommended for cancellation for thus use, it was not evaluated as a viable alternative.

The extent of the use of EDB in both vault fumigation of stored clothing and furniture, and in the APHIS/USDA Japanese beetle quarantine program is unknown. The economic benefits therefore, could not be quantified. A registered acceptable alternative in the APHIS/USDA quarantine program is methyl bromide. Four registered alternatives are available for vault fumigation: a carbon tetrachloride/ethylene dichloride mixture, chloropicrin, methyl bromide, and sulfuryl fluoride. However, methyl bromide requires extreme care in use, as described in Chapter III.

2. Risk/Benefit Analysis

The Agency has concluded that sufficient information exists to propose cancelling the use of EDB to fumigate felled logs. The basis for this decision lies in the fact that applicators are at risk to unreasonable adverse effects of EDB, and because there are no known benefits for this use. Use of endosulfan in place of EDB would result in a total reduction in treatment costs of about $36,000 annually, even though it is not as effective as EDB. The Agency concludes that the potential health risks to applicators through both dermal contact and inhalation exposures to EDB outweigh these negative benefits.

In view of the lack of risk and benefit information for the remaining three uses, the Agency is unable to perform an adequate risk-benefit balancing analysis. However, because applicators could potentially experience unreasonable adverse effects of EDB, the Agency will require registrants to submit certain data necessary to adequately evaluate the risks and benefits of each of these lower uses. Because time will be needed to obtain these data, evaluate it, and perform a thorough risk-benefit balancing, for the interim the Agency has examined a number of actions designed to reduce applicator risks at a minor cost. Summarized below by use are actions the Agency is proposing and data which the Agency will require of registrants. These are organized on a use-by-use basis for three of the four minor uses: fumigation of beehives and supers, APHIS Japanese Beetle Control Program, and vault fumigation.

For fumigation of beehive supers and honeycombs, the Agency is proposing the following interim label changes for such EDB products:

Certified Applicators -- Fumigation may be conducted only by or under the supervision of a certified applicator.

Protective Clothing -- EDB-resistant gloves (butyl rubber only), boot covers and apron (made of butyl rubber, nitrile, or polyethylene) will be worn at all times.

Use Directions -- Supers and honeycombs must be placed in a gas-tight room or under a gas-tight covering such as a polyethylene tarpaulin held down with sand-filled "snakes." All windows, doors and vents must sealed. All persons not involved with the fumigation must be vacated from the building.

Reentry Period -- Following the treatment period, a full-face, black canister respirator must be worn when reentering. All doors, windows and vents must be opened at this time. Aeration for 24 hours or until EDB air levels are less than 0.4 ppm measured by IR detector shall be required before reentry is permitted. The label and warning signs (See Chapter IV) must contain this information.

Limit fumigation to beehive supers that are clean and in storage. -- To avoid possible contamination of honey or honeycombs, the label will prohibit treatments other than on clean supers or comb mounted in frames in storage. This restriction is in accordance with current practice.

In addition to these label changes, the Agency is proposing to require the following data from registrants:

1. EDB air levels to which applicators are exposed during typical conditions of use.

2. Number of users.

3. Residue studies to determine if EDB is detectable in honey from fumigated supers and combs.

For vault storage, the Agency is proposing to require the following label changes and use restrictions:

Protective Clothing -- Require the same protective clothing listed for beehive supers.

Certified Commercial Applicators -- Vault fumigation may be conducted only by certified commercial applicators in commercial fumigation vaults.

Use Directions -- Before fumigation, all doors and leaks in the vault must be sealed. All persons not involved with the fumigation must be vacated from the building.

Reentry Period -- Following the treatment period, a full-face, black canister respirator must be worn during reentry. All doors and vents in the treatment area and connected buildings must be opened at this time. Premises must be aerated 24 hours or until EDB levels are less than 0.4 ppm as measured by IR detector before reentry is allowed. Posted warning signs (See Chapter IV) must bear this information.

In addition to these label changes, the Agency proposes to require the following information from registrants:

1. Monitoring studies of the EDB air levels to which applicators may be exposed, both during pouring EDB into dispensing containers and also during reentry into the vault after fumigation.

2. Survey data on the number of vault fumigation operations using EDB and the number of applicators involved in this practice; and

3. Data on the amount of EDB applied annually for this use.

For the APHIS Japanese Beetle Control Program, the Agency is proposing to require the following label restrictions and revisions in the APHIS Manual:

Grass sod -- Treated sod must be covered with a heavy plastic or tarp during the treatment period to ensure an efficacious treatment and to minimize air exposures. The tarp must be aired before re-use.

Bareroot Plants -- The proper method for disposing of the used EDB-water mixture must be specified.

Balled or Containerized Plants -- The "enclosed place" into which plants are placed after treatment must be posted with signs indicating the minimal reentry information described previously. Proper disposal methods must be described.

Potting and Bench Soil -- Soil must be covered with plastic or heavy tarp for duration of the treatment period.

Beds and Other Uses -- Soil must be covered with plastic or heavy tarp for duration of the treatment period.

For All Above Uses -- The APHIS Manual states for balled or containerized plants that treatment is approved only when beetle grubs (larvae and pupae) are present. This requirement must be imposed for all regulated articles to avoid unnecessary applications.

For this use, the Agency is proposing to require the following information:

1. Monitoring studies of the air levels to which applicators are exposed during mixing and during use.

2. Data on the amount of EDB used annually, the number of applicators and the frequency of use.

In addition to these actions, the Agency is proposing to require certain interim measures for the use of EDB in the control of termites. As discussed earlier, the Agency is proposing to defer a risk/benefit balancing decision for this use and will include it in a cluster analysis of all pesticides used for termite control. In the interim, however, the Agency recognizes that both applicators and persons in the immediate treatment area can be exposed and are therefore at risk to unreasonable adverse affects. To reduce exposures of applicators and non-involved persons to EDB, the Agency proposes the following use restrictions be included on the label:

Certified Commerical Applicators -- Fumigation may be conducted only by a certified commercial applicator wearing a full-face, black canister respirator;

Protective Clothing -- EDB-resistant gloves, boot covers and apron will be required at all times;

Use Directions for Drywood Termites -- Persons not involved with the fumigation must leave the premises. Holes of size and spacing specified by the registrant must be drilled and the recommended dosage of EDB injected into these holes using a calibrated syringe or like device.

Use Directions for Subterranean Termites -- Persons not involved with the fumigation must leave the premises before fumigation and subsequent aeration. Use is not permitted under slabs which contain air ducts, electrical conduits, or the like. Recommended dosage must be injected through holes drilled in concrete slabs which support infested structures. All holes must be plugged temporarily to prevent the escape of EDB during treatment, and must be sealed permanently immediately after treatment. The label must state these requirements.

Reentry Period -- During and after fumigation all doors, windows and vents in the treatment area and connected buildings would be opened. Premises must be aerated 24 hours or until EDB air levels are below 0.4 ppm before reentry is permitted. The label and posted warning signs must contain this information.

In addition, the Agency is proposing to require registrants to provide data which would be needed in the cluster analysis. These data are:

1. Air concentration of EDB to which applicators are exposed, their annual time spent using EDB, the number of applicators using EDB in the U.S., and the amount of formulation sold annually; and

2. Air monitoring studies which investigate the potential EDB air levels to which persons not involved can be exposed. These would include indoor places at or near the site(s) of application.

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APPENDIX 1

RESPONSES RECEIVED REBUTTING HEALTH TRIGGERS

Rebuttal No.	Source	Date of Submission [1]
3C	Great Lakes Chemical Corporation	01/23/78
7	Chevron Chemical Company	01/16/78
13	University of Idaho Cooperative Extension Service	01/19/78
14	Department of Citrus, State of Florida	01/20/78
15	Millers National Federation	01/24/78
15A	Millers National Federation	04/07/78
15B	American Corn Millers Federation	04/07/78
16	Colorado State University	01/26/78
22	Ferguson Fumigant Inc.	01/31/78
22A	Ferguson Fumigant Inc.	02/01/78
22B	Ferguson Fumigant Inc.	04/04/78
22C	Ferguson Fumigant Inc.	04/13/78
22D	Ferguson Fumigant Inc.	06/01/78
26	Pineapple Growers Association of Hawaii, Honolulu	12/12/77 [2]
31	Florida Agricultural Research Institute	01/31/78
32	Florida Farm Bureau	01/31/78
33	Department of Agriculture Honolulu, Hawaii	01/31/78
47	Douglas Chemical Company	02/09/78
47A	Douglas Chemical Company	04/13/78
48	Ethyl Corporation	01/31/78
64	Vulcan Materials Company, Chemical Division	04/03/78
65	Florida Citrus Commission	04/03/78

66	Environmental Defense Fund	04/04/78-04/03/79
78	Dow Chemical	04/26/78
79	Cooperative Extension, University of California	04/11/78

1/ Dates given are the dates OPP's Federal Register Section received the submission.

2/ Three additional addenda were submitted on this rebuttal.

APPENDIX 2

FROM FOOD IRRADIATION NEWSLETTER
OCTOBER 79, IAEA

LIST OF CLEARANCES

GENERAL SURVEY OF IRRADIATED FOOD PRODUCTS CLEARED FOR HUMAN CONSUMPTION IN DIFFERENT COUNTRIES

(Grouped according to country) August 1979

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION	DOSE (k Gy)	DATE OF APPROVAL
BULGARIA	potatoes *)	sprout inhibition	+		1971
	potatoes *)	sprout inhibition	+	0.1	30 April 1972
	onions *)	sprout inhibition	+	0.1	30 April 1972
	garlic *)	sprout inhibition	+	0.1	30 April 1972
	grain *)	sprout inhibition	+	0.3	30 April 1972
	dry food concentrates *)	insect disinfestation	+	1	30 April 1972
	dried fruits *)	insect disinfestation	+	1	30 April 1972
	fresh fruits *) (tomatoes, peaches, apricot, cherry, raspberry, grapes)	radurization	+	2.5	30 April 1972

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION			DOSE (k Gy)	DATE OF APPROVAL
			^{60}Co	^{137}Cs	electrons		
CANADA	potatoes	sprout inhibition	+			0.1 max	9 November 1960
						0.15 max	14 June 1963
	onions	sprout inhibition	+			0.15 max	25 March 1965
	wheat, flour, whole wheat flour	insect disinfestation	+			0.75 max	25 February 1969
	poultry ****)	radicidation (Salmonella)	+			7 max	20 June 1973
	cod & haddock fillets ****)	radurization	+			1.5 max	2 October 1973
CHILE	potatoes *) ****)	sprout inhibition	+				31 October 1974
CZECHOSLOVAKIA	potatoes *)	sprout inhibition	+			0.1 max	26 November 1976
	onions *)	sprout inhibition	+			0.08 max	26 November 1976
	mushrooms *)	growth inhibition	+			2 max	26 November 1976
DENMARK	potatoes	sprout inhibition			10 MeV	0.15 max	27 February 1970

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION			DOSE (k Gy)	DATE OF APPROVAL
			^{60}Co	^{137}Cs	electrons		
FRANCE	potatoes **)	sprout inhibition	+			0.075 - 0.15	8 November 1972
	onions **)	sprout inhibition	+	+		0.075 - 0.15	9 August 1977
	garlic **)	sprout inhibition	+	+		0.075 - 0.15	9 August 1977
	shallot **)	sprout inhibition	+	+		0.075 - 0.15	9 August 1977
FRG	deep-frozen meals *) ***)	radappertization	+			25 -45	24 March 1972
	potatoes *)	sprout inhibition	+			0.15 max	26 September 1974
HUNGARY	potatoes ****)	sprout inhibition	+			0.1	23 December 1969
	potatoes ****)	sprout inhibition	+			0.15 max	10 January 1972
	potatoes ****)	sprout inhibition	+			0.15 max	5 March 1973
	onions ****)	sprout inhibition	+				5 March 1973
	onions ****)	sprout inhibition	+			0.06	6 August 1975
	onions *)	sprout inhibition	+			0.06	6 September 1976
	strawberries ****)	radurization	+				5 March 1973

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION			DOSE (k Gy)	DATE OF APPROVAL
			^{60}Co	^{137}Cs	electrons		
HUNGARY (cont'd.)	mixed spices [*] (blackpepper, cumin, paprika, dried garlic: for use in sausages)	radicidation	+			5	2 April 1974
	mixed dry ingredients for canned hashed meat [*]) (wheat flour, Na caseinate, onions and garlic powder, paprika)	radiation decontamination	+			5	20 November 1976
ISRAEL	potatoes	sprout inhibition	+			0.15 max	5 July 1967
	onions	sprout inhibition	+			0.1 max	25 July 1968
ITALY	potatoes	sprout inhibition	+			0.075 - 0.15 max	30 August 1973
	onions	sprout inhibition	+			0.075 - 0.15	30 August 1973
	garlic	sprout inhibition	+			0.075 - 0.15	30 August 1973
JAPAN	potatoes	sprout inhibition	+			0.15 max	30 August 1972

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION ^{60}Co	^{137}Cs	electrons	DOSE (k Gy)	DATE OF APPROVAL
NETHERLANDS	asparagus *)	radurization	+			2 max	7 May 1969
	cocoabeans *)	insect disinfestation	+		4 MeV	0.7 max	7 May 1969
	strawberries ****)	radurization	+		4 MeV	2.5 max	7 May 1969
	mushrooms	growth inhibition	+		4 MeV	2.5 max	23 October 1969
	deep-frozen meals ***)	radappertization	+			25 min	27 November 1969
	potatoes	sprout inhibition	+		4 MeV	0.15 max	23 March 1970
	peeled potatoes ****)	radurization	+			0.5	12 May 1976
	shrimps *)	radurization	+		4 MeV	0.5 - 1	13 November 1970
	shrimps ****)	radurization	+			1	15 June 1976
	onions *)	sprout inhibition	+			0.15 max	5 February 1971
	onions	sprout inhibition	+			0.05 max	9 June 1975
	poultry, eviscerated (in plastic bags)	radurization	+			3 max	31 December 1971

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION			DOSE (k Gy)	DATE OF APPROVAL
			^{60}Co	^{137}Cs	elec-trons		
NETHERLANDS (cont'd.)	chicken	radurization, radicidation	+			3 max	10 May 1976
	fresh, tinned & liquid foostuffs ***)	radappertization	+			25 min	8 March 1972
	spices & condiments *)	radicidation	+		4 MeV	8 - 10	13 September 1971
	spices **)	radicidation	+		4 MeV	10	4 October 1974
	spices **)	radicidation	+		3 MeV	10	26 June 1975
	spices **)	radicidation	+			10	4 April 1978
	vegetable filling *) ****)	radicidation	+			0.75	4 October 1974
	powdered battermix ****)	radicidation	+			1.5	4 October 1974
	endive ****) (prepared, cut)	radurization	+			1	14 January 1975
	fresh vegetables ****) (prepared, cut, soupgreens)	radurization	+			1	6 September 1977

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION ^{60}Co	^{137}Cs	elec-trons	DOSE (k Gy)	DATE OF APPROVAL
NETHERLANDS (cont'd.)	fillets of haddock, coal-fish, whiting ****)	radurization	+			1	6 September 1976
	fillets of cod & plaice ****)	radurization	+			1	7 September 1976
	frozen frog legs **)	radicidation	+			5	25 September 1978
	rice and ground rice products **)	disinfestation	+			1	13 March 1979
PHILIPPINES	potatoes **)	sprout inhibition	+			0.15 max	13 September 1972
SOUTH AFRICA	potatoes	sprout inhibition delayed greening	+			0.12 - 0.24	19 January 1977
	onions	sprout inhibition	+			0.05 - 0.15	25 August 1978
	garlic	sprout inhibition	+			0.1 - 0.20	25 August 1978
	chicken	radurization radicidation	+			2 - 7	25 August 1978
	papaya	radurization	+			0.5 - 1.5	25 August 1978

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION			DOSE (k Gy)	DATE OF APPROVAL	
			^{60}Co	^{137}Cs	elec-trons			
SOUTH AFRICA (cont'd.)	mango	radurization	+			0.5 - 1.5	25 August	1978
	strawberries	radurization	+			1 - 4	25 August	1978
	dried bananas +)	insect disinfestation	+			0.5 max	28 July	1977
	avocados +)	delayed ripening	+			0.1 max	28 July	1977
SPAIN	potatoes	sprout inhibition	+			0.05 - 0.15	4 November	1969
	onions	sprout inhibition	+			0.08 max		1971
THAILAND	onions	sprout inhibition	+			0.1 max	20 March	1973
UNION OF SOVIET SOCIALIST REPUBLICS	potatoes	sprout inhibition	+			0.1	14 March	1958
	potatoes	sprout inhibition			1 MeV	0.3	17 July	1973
	grain	insect disinfestation	+			0.3		1959
	fresh fruits & vegetables a)	radurization	+			2 - 4	11 July	1964

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION			DOSE (k Gy)	DATE OF APPROVAL	
			^{60}Co	^{137}Cs	elec-trons			
UNION OF SOVIET SOCIALIST REPUBLICS (cont'd.)	semi-prepared raw beef, pork & rabbit products (in plastic bags) *)	radurization	+			6 - 8	11 July	1964
	dried fruits	insect disinfestation	+			1	15 February	1966
	dry food concentrates (buckwheat mush, gruel rice pudding)	insect disinfestation	+			0.7	6 June	1966
	poultry, eviscerated (in plastic bags) *)	radurization	+			6	4 July	1966
	culinary prepared meat products (fried meat, entrecote) (in plastic bags) *)	radurization	+			8	1 February	1967
	onions *)	sprout inhibition	+			0.06	25 February	1967
	onions	sprout inhibition	+			0.06	17 July	1973

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION ^{60}Co	^{137}Cs	electrons	DOSE (k Gy)	DATE OF APPROVAL
UNITED KINGDOM	any food for consumption by patients who require a sterile diet as an essential factor in their treatment	radappertization					1 December 1969
UNITED STATES OF AMERICA	wheat and wheat flour (changed on 4 March 1966 from wheat and wheat product)	insect disinfestation	+			0.2 - 0.5	21 August 1963
				+		0.2 - 0.5	2 October 1964
					5 MeV	0.2 - 0.5	26 February 1966
	white potatoes	sprout inhibition	+			0.05 - 0.1	30 June 1964
				+		0.05 - 0.1	2 October 1964
			+	+		0.05 - 0.15	1 November 1965
URUGUAY	potatoes	sprout inhibition	+				23 June 1970

COUNTRY (Organization)	PRODUCT	PURPOSE OF IRRADIATION	TYPE AND SOURCE OF RADIATION			DOSE (k Gy)	DATE OF APPROVAL
			^{60}Co	^{137}Cs	electrons		
WORLD HEALTH ORGANIZATION	potatoes **)	sprout inhibition	+	+		0.15 max	12 April 1969
(FAO/IAEA/WHO Expert Committee)	potatoes	sprout inhibition	+	+	10 MeV max	0.03 - 0.15	7 September 1976
	onions +)	sprout inhibition	+	+	10 MeV max	0.02 - 0.15	7 September 1976
	papaya	insect disinfestation	+	+	10 MeV max	0.5 - 1	7 September 1976
	strawberries	radurization	+	+	10 MeV max	1 - 3	7 September 1976
	wheat & ground wheat products **)	insect disinfestation	+	+	10 MeV max	0.75 max	12 April 1969
	wheat & ground wheat products	insect disinfestation	+	+	10 MeV	0.15 - 1	7 September 1976
	rice +)	insect disinfestation	+	+	10 MeV max	0.1 - 1	7 September 1976
	chicken	radurization radicidation	+	+	10 MeV max	2 - 7	7 September 1976
	cod & redfish +)	radurization radicidation	+	+	10 MeV max	2 - 2.2	7 September 1976

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*) experimental batches
**) temporary acceptance
***) hospital patients
****) test marketing
+) provisional
underlined: unlimited clearance (uncondtional acceptance: WHO)

APPENDIX II

COMMENTS RECEIVED IN RESPONSE TO PD 2/3

Comment No.	Source
1	W.B. McCloud & Co.
2	Millers National Federation
3	County of San Diego Department of Agriculture
4	Florida State Beekeepers Assoc.
5	State of Hawaii
6	Anheuser-Busch, Inc.
7	The American Beekeeping Federation
8	American Corn Millers Federation
9	Butte County Mosquito Abatement District
10	California Farm Bureau Federation
11	LeBost, Mr. & Mrs. Deerfield
12	Jackson County Farm Bureau
13	Boettcher Supply, Inc.
13A	Reiling, Mr. Gregg
14	Ohio Dept. of Agriculture
15	Colorado State Forest Service Colorado State University
15A	Colorado State Forest Service Colorado State University
16	University of Nebraska-Lincoln Cooperative Extension Service
17	State of North Carolina Dept. of Agriculture
18	Crawford, Mr. Johnny L.
18A	University of Georgia College of Agriculture, Cooperative Extension Service

APPENDIX III

FEDERAL INSECTICIDE, FUNGICIDE, AND RODENTICIDE ACT (FIFRA)

SCIENTIFIC ADVISORY PANEL

Review of Preliminary Notice of Determination Concluding the Rebuttable Presumption Against Registration (RPAR) of Pesticide Products Containing Ethylene Dibromide (EDB)

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) Scientific Advisory Panel has completed review of plans by the Environmental Protection Agency (EPA) for initiation of regulatory action on pesticide products containing ethylene dibromide (EDB) under the provisions of Section 6(b)(2) of FIFRA as amended. The review was completed in an open meeting held in Arlington, Virginia, on March 25-26, 1981.

Maximum public participation was encouraged for the review. Public notice of the meeting was published in the Federal Register on February 25, 1981. In addition, telephone calls were received from and mailings sent to the general public who had previously expressed an interest in activities of the Panel. Oral, and in most cases, written statements were received from the technical staff of EPA's Office of Pesticide Programs, and from representatives of the U.S. Department of Agriculture; the State of Florida, Department of Citrus; Ethyl Corporation; the University of California; the Hawaii papaya industry; Dow Chemical Corporation; National Pest Control Association; Hopes Consulting Company; National Association of Wheat Growers; Emergent Technologies, Incorporated; and Radiation Dynamics, Incorporated.

The excellent briefings by the staff of OPP's Special Pesticide Review Division (SPRD) were of great value to the Panel. The Panel wishes to express its appreciation to SPRD for having prepared a Position Document 2/3 on EDB of very high quality. Also, the Panel would like to thank Dr. Carol Sakai, Reproductive Effects Assessment Group, EPA, for an outstanding scientific briefing on the reproductive effects of EDB.

In consideration of all matters brought out during the meeting and careful review of all documents presented by the Agency and other parties, the Panel unanimously submits the following report:

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REPORT OF SCIENTIFIC ADVISORY PANEL RECOMMENDATIONS

The Agency requested the Panel to focus its attention upon these issues:

1. The data requirements (ground water, food residues for pre-plant, exposures and survey data for minor uses applicator)

2. The acceptability of risks during the phase out of citrus

3. The similarities of this pesticide to dibromochloropropane (DBCP)

   o use sites

   o health risks

   o chemical structure

4. The acceptability of alternatives relative to the toxic hazards of EDB expecially for grain and citrus.

The Panel's response to each of the above issues is as follows:

1. The data requirements (ground water, food residues for pre-plant, exposures and survey data for minor uses applicator)

The Panel expresses considerable concern over the potential human hazard as a result of the spot fumigation in flour mills use of Ethylene Dibromide (EDB) and recommends that EPA require a thorough and critical study of EDB residues in grain, as well as obtain residue data in bread and other bakery products.

The Panel also indicates its concern over the possible appearance of EDB in ground water, and urges that ground water be monitored closely in high use areas.

The Panel recommends that a reproductive study on rodents be performed with critical structural and functional analysis of endocrine, reproductive and fetal tissues.

Finally, the Panel recommends that EPA monitor high risk workers in the grain, citrus and minor use areas, both during and following exposure.

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2. The acceptability of risks during the phase out of citrus

The Panel differs with the Agency's position that EDB use on citrus should be phased out by July 1983. Rather, the Panel proposes that this use be retained in a similar manner as several other uses which the Agency is proposing be allowed, but with certain restrictions imposed, including pre-plant fumigation of soil, stored beehive fumigation, stored furniture and clothing, and nursery stock. The reason for this is that the Panel finds it difficult to evaluate whether it is feasible for the citrus industry to move to irradiation as an alternative to EDB control of fruit flies. Therefore, the Panel recommends reevaluation of the risks and benefits of irradiation as an alternative for EDB as soon as possible.

In the meantime, the Panel recommends the use of additional protactive measures to reduce worker exposure. It appears to the Panel that substantial improvements can be made in EDB application technology, and that such improvements will reduce both the number of workers exposed and the severity of the exposure.

3. The similarities of EDB to DBCP with regard to chemical structure, use sites and health risks

The Panel finds that EDB has certain structural qualities, uses and adverse effects which resemble those of DBCP. However, extrapolation from one compound to another entails the same kind of uncertainties as does extrapolation in testing from one species to another. Therefore, the Panel recommends that the data be obtained on EDB directly rather than on the basis of extrapolation from other compounds.

4. The acceptability of alternatives relative to the toxic hazards of EDB especially for grain and citrus

The Panel finds that alternatives to EDB appear to be available in several areas, e.g., fumigation of stored grain, termite control, bark beetle control and other minor uses. Alternatives for soil fumigation and citrus are not well developed and clearly demonstrated to be efficient, practical, and feasible from a cost standpoint.

The Panel's response to the issues listed by EPA as regards EDB is based on the following evaluation of the available data base for this agent:

1. EDB is a carcinogen for multiple animal species of both sexes producing oncogenic effects in several tissues following exposure by at least two routes of administration.

2. EDB is a potent mutagen producing point (gene) mutation, chromosomal aberration and primary DNA damage in multiple test systems involving both prokaryotic and eukaryotic systems (including mammals).

3. EDB has been demonstrated to produce adverse reproductive effects in several species. None of these studies definitively demonstrates a no observed effect level (NOEL). As indicated above, the Panel recommends that a reproduction study in rodents be required to characterize the threshold dosage level for EDB effects on fertility, mating, gestation, etc.

The Panel notes that it will be very difficult to conduct epidemiological studies that will enable EPA to ignore the results of animal studies. Such epidemiological studies which have been conducted thus far do not provide convincing evidence that animal tests do not accurately predict potential human hazards in the area of oncogenicity and reproductive effects. Therefore, it is necessary to regulate on the basis of animal studies alone.

The Panel wishes to make a clear distinction between the apparent hazards of citrus and grain fumigation insofar as human dietary factors are concerned, and thus does not concur with the Agency's proposal to cancel the use of EDB on citrus. As regards stored grain fumigation and spot fumigation of grain milling machinery, the Panel wishes to express its great concern over the possible presence of EDB residues in finished bakery products. The evidence is far from solid, but because of the extremely large population potentially at risk, the problem demands resolution. Therefore, the Panel concurs with the EPA proposal to cancel stored grain fumigation and spot fumigation of grain milling machinery uses until such time as convincing evidence exists that such uses present little or no hazard to consumers of bakery products.

FOR THE CHAIRMAN:

Certified as an accurate report of findings:

P. H. Gray

Philip H. Gray, Jr.
Acting Executive Secretary
FIFRA Scientific Advisory Panel

Date: April 22, 1981

DEPARTMENT OF AGRICULTURE
OFFICE OF THE SECRETARY
WASHINGTON, D C. 20250

April 6 1981

Honorable Walter C. Barber, Jr.
Acting Administrator
U. S. Environmental Protection Agency
Washington, D. C. 20460

Dear Mr. Barber:

This is the U. S. Department of Agriculture's response to the U. S. Environmental Protection Agency's Preliminary Notice of Determination concluding the Rebuttable Presumption Against Registration (RPAR) of pesticide products containing ethylene dibromide (EDB).

We concur in the decision to continue use of EDB for soil fumigation and to the postponement of a decision on several other uses pending receipt of additional data. We do not concur that EDB should be cancelled for fumigation of felled logs, or for quarantine purposes. It is our conclusion that there is insufficient information to adequately indicate that gamma irradiation is or will be a feasible substitute for EDB quarantine fumigation on a broad scale basis by July 1, 1983. We believe that in light of new information on use and the lack of viable alternatives the actions on these uses of EDB should be reevaluated.

We agree that more data are needed on residue levels of EDB on treated and processed commodities as well as more data on the effectiveness of worker and applicator protection techniques associated with EDB. We will cooperate with EPA and industry to provide additional data as necessary.

Our specific comments are contained in the enclosure which is an integral part of this response. In view of the complex issues involved, the additional time that your agency granted for review of this document was very beneficial and is appreciated.

Sincerely,

John R Block

John R. Block
Secretary

Enclosures

SECRETARY OF AGRICULTURE'S SPECIFIC COMMENTS TO EDB NOTICE OF DETERMINATION PD 2/3

I. Preplant Soil Fumigation

USDA is willing to provide input and assistance to EPA and industry to develop acceptable experimental design and/or additional data to resolve concerns associated with potential residues on crops grown in soil that has been treated with EDB.

II. Fumigation of Stored Grain

More recent data has been developed from an interagency study in SEA:AR, ASCS, and FGIS, which is now in progress to measure the level of insect and fungal activity in farm stored grain. This study consists of grain samples and storage information from about 4,000 bins of wheat, 3,000 bins of corn, and 1,000 bins of oat stored on farms in 20 States. Storage information obtained in this study includes a record of measures taken by the producer to maintain the quality of the grain during storage. Preliminary analysis of these data indicated that less than 3 percent of the wheat bins and less than 1 percent of the corn and oat bins were fumigated during the 1-4 year on-farm storage. Fumigation occurred most often during the second year of storage, generally in the late summer or early fall. Fumigant materials identified as being used in the farm treatment included aluminum phosphide, chloropicrin, and a liquid fumigant mixture composed entirely of carbon tetrachloride (CCl_4) and carbon disulphide (CS_2) (80:20) or these two used in conjunction with 1.2 to 5 percent ethylene dibromide.

An interim analysis of EDB use in on-farm storage may be estimated from the study now in progress which shows the following percentages of grain being treated with EDB.

Grain in Storage	Amount in Storage (1,000 bushels)	% Treated	Lbs. EDB Used
Wheat	972,054	2.0	52,492
Corn	2,494,504	0.5	4,489
Oats	388,625	0.25	349
Barley	240,442	0.25	108
Sorghum	39,708	0.25	54

The results of this study are expected to be tabulated in computer storage by May 1, 1981.

EDB liquid fumigant formulations are labelled for use in both on-farm and commercial elevator storage. In actual practice EDB fumigation of stored grain is concentrated in on-farm storage. Liquid formulations were developed specifically for this purpose. EDB is included in liquid grain fumigants to improve effectiveness in the upper layer of the treated grain. In the event of the cancellation of EDB for this use, farmers would have to switch to a less efficient liquid fumigant, 80 percent carbon tetrachloride/20 percent carbon disulfide or phosphine. Carbon tetrachloride is presently under RPAR review. The additional applications necessary for comparable control would result in both increased expense and exposure hazard because of lower efficiency.

Some level of mixing with untreated grain would be expected in movement from on-farm storage, in further movement from the elevator, as well as mixing in the milling or other processing operations. The level of EDB (as organic bromide) in most processed products should, therefore, be low.

Because of the changes in use patterns and the current availability of more accurate data on the volume of use, EPA's proposed regulatory action regarding fumigation of stored grains should be reevaluated.

III. Spot Fumigation of Grain Milling Machinery

Three types of fumigant formulations containing EDB have been used in the fumigation of milling machinery. The two liquid types contained (CCl_4), ethylene dichloride (EDC) and EDB in different proportions. The third type was a gaseous mixture of 70 percent EDB and 30 percent methyl bromide. Today, virtually the entire EDB usage in this industry involves the application of this 70:30 mixture and only one company is currently formulating it. The annual use of EDB for this purpose was originally estimated at 465,000 lbs. Interim data from the study mentioned previously indicate this use at approximately 162,000 lbs. The original estimate was based primarily on the use of the EDB liquid fumigant mixture and does not accurately reflect use of the present 70:30 mixture in the milling industry. As with grain fumigation, the exposure resulting from the amount of EDB known to be applied is much less than originally estimated.

The primary alternative to spot fumigation is general fumigation of the entire structure. However, general fumigation is not feasible at the frequency necessary to obtain control equivalent to spot fumigation. Most mills cannot close completely for several days at a time. To obtain adequate insect control, mills would have to shut down four or more times per year. In addition, specialized mills such as those located in breweries cannot use either methyl bromide or phosphine in their plants because of the corrosive effects of these fumigants on materials in nonmilling areas of the facility. The use of EDB does not pose this problem. The common use of manifold systems in spot fumigations serves to remove applicators from sites of gas generation, lessens the risk of spillage on applicators, and thus reduces hazards to these personnel.

Good sanitation in milling areas is necessary for effective pest control; however, it will not serve as an alternative to EDB use which is still required since milling residues collect in unaccessible places in the machinery. The only alternative is spot treatment with a fumigant.

Because of the changes in use patterns to the gaseous 70:30 mixture in the past few years, the current availability of more accurate data on volume of use, and the fact that proposed alternatives are not economically feasible and are associated with high risk, we strongly feel that EPA's proposed regulatory action regarding spot fumigation of milling machinery similarly should be reevaluated. EPA should strongly consider and evaluate the use of protective clothing and other safety options to minimize risk as an alternative to cancelling this critical use.

IV. Quarantine Fumigation

The registration for post harvest commodity quarantine uses should be continued for the following reasons:

1. As noted by EPA, there is presently no effective and practical alternative to EDB for these uses. The assumption that irradiation will be available by July 1983 is unrealistic. Although EPA has evidently had interaction with specialists in the field of irradiation, we are unaware of data demonstrating the feasibility of irradiation as a near term, viable, on-line alternative for bulk quantities of fruit. Data concerning the timeframes for getting on-line, chamber design, as well as design and on-line costs should be made available. Research has been conducted by USDA, as well as other groups in Hawaii, California, Florida, Illinois, Massachusetts, and elsewhere, to determine if fresh fruits and vegetables will tolerate insect destroying rates of gamma irradiation. Much of this research is outlined in "The Proceedings of a Panel on The Use of Irradiation to Solve Quarantine Problems in the International Fruit Trade." (Attached) The panel was organized by the joint Foreign Agriculture Organization and the International Atomic Energy Agency, Division of Atomic Energy in Food and Agriculture and held in Honolulu, Hawaii, in December 1970. A petition (FAP 3045) from USDA to FDA requesting approval of the use of gamma irradiation on papaya was submitted to FDA in 1973. The Food and Drug Administration has not acted on this petition during the past eight-year period. A new petition relating to these uses is in preparation. Additional research is needed on mango and papaya as well as citrus and other fruit to determine dosages necessary to control insect pests, potential injury to fruit, and chemical or other changes in fruit composition including feeding studies on nutritional value. This data collection will require considerable time and expense.

2. EPA noted in its Notice of Determination that USDA's estimated benefits of post harvest commodity treatments on grapefruits for export market to Japan may be substantially overstated. The benefits estimates were premised on the assumption that the grapefruit export market to Japan will be lost if this registered use is cancelled. This assumption has been validated. Communication with the Government of Japan since the publication of PD 2/3 indicates that Japan will not approve of gamma irradiation as an alternative to EDB fumigation. The refusal is primarily on the basis that irradiation at the dosages used does not actually kill all fruitflies. In addition, Japan has indicated that even the effective use of gamma irradiation may still not be acceptable. However, they did state that they would continue to accept EDB treated fruit. (See attached letter of February 12, 1981, from American Embassy, Tokyo.) Recent studies (SAND 79-1727, Attachment B) suggest that dosages of 25 to 75 K-rads will sterilize fruitfly larvae, but not kill them. However, this study did not statistically evaluate the effects of varying dosages of gamma irradiation on fruitfly egg, larval and pupal sterility and mortality, when infested commodities are subjected to irradiation. The results are of limited value in assessing gamma irradiation as an alternative to EDB for commodity treatment.

3. As indicated in USDA's biologic and economic assessment report, citrus and tropical fruits are imported from countries such as Mexico, Haiti, Israel, and Morocco, thereby strengthening our trade positions with them. Of the crops received from those countries, cold treatment can only be used for oranges and is limited to certain insect growth stages at the time the fruit is harvested. The facilities for such treatment are not available and must be constructed and approved before shipments could be initiated. Further, in the case of Mexican oranges in addition to the expense involved, the delay of a minimum of three weeks for cold treatment would bring their fruit into competition with the California harvest and could virtually eliminate Mexican fruit from the U. S. market. In these cases, the Department's quarantine requirements cannot be met without the use of EDB.

4. EDB fumigation chamber operation, construction, and personnel safety specifications are available to meet or exceed proposed OSHA safety standards. A revised section of the PPQ Treatment Manual on EDB Fumigation Chambers was issued in July 1980. Fumigation conducted at packing sheds in Texas and Hawaii currently meet the proposed 0.13 ppm (time weighted average) for worker exposure. Further, a study was recently conducted entitled, "Behavioral Effects of Prenatal Exposure to Ethylene Dibromide." This study indicates that an exposure of 6.67 ppm EDB for four hours per day on alternate days throughout gestation did not result in an observable behavioral effect to the study animals. Tests determined that maternal behavior, sensorimotor coordination, activity, passive avoidance, complex learning and motivation were unaffected at exposure levels in the offspring of exposed pregnant Long-Evans hooded rats. (These documents are attached.)

5. The proposed cancellation of EDB post harvest fumigation of citrus, tropical fruits and vegetables should not occur. This determination can be based upon the newly available safety data contained herein and the lack of effective alternatives. A reevaluation could be made when all the foregoing questions have been resolved.

   EPA should strongly consider and evaluate the use of protective clothing and other safety options to minimize risk as an alternative to cancelling these critical uses.

V. Fumigation of Felled Logs

EDB is an important use in the control of bark beetles where non-chemical control methods, including site selection and thinning, are not viable control options. EDB is only used after an infested tree has been cut. If the tree is not treated to destroy the beetles, they will emerge and attack adjacent trees. The proposed alternative, endosulfan, is not specifically registered for the particular insect of concern which is the mountain pine beetle (Dendroctonus ponderosae). There is no efficacy data comparing its effectiveness with EDB. Lindane would be the preferred alternative although it was not considered by EPA as a viable alternative due to its RPAR status.

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